Snell and Law Building Parking Lot Flood Prevention

Storm Drain Design

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Table of Contents

Introduction
The purpose of this project is to design a storm water drainage system to prevent flooding of the Snell Building and its surrounding area on the campus of Brigham Young University. As the reparations for flooding of university facilities can cost on the order of magnitude of millions of dollars, the redesign of storm water drainage for the parking lot between the Snell Building and Law Building is under consideration.

Background
In July 2011, two major flood events on the campus of Brigham Young University (BYU) brought attention to the need to redesign the storm drainage system for the parking lot between the Law and Snell buildings. The events damaged the recently remodeled Snell building and the landscaping that was placed around the building. As part of the redesign of the building, a berm was placed on the north side of the building to protect it from potential flooding; however, the flood events in the summer of 2011 removed the sod from the top of the berm and washed away the soil that was placed to act as a berm.

Scope
To prevent future flooding around the Snell Building, a new drainage system is needed. This project requires an analysis of the collection and distribution system capacities to understand deficiencies. Site visits paired with aerial contour and utility maps provided by BYU will be used to understand the current system. After examining the current system, flooding hazards for a 25-year storm and a 50-year storm are to be determined.

Once the current capacities and potential flooding hazards are determined, multiple solution alternatives are prepared. Each solution is presented with an evaluation of its benefits, potential problems, and cost. A recommended design is also noted after an evaluation of the proposed plans.

Constraints
Regarding cost, it was only made known to us by Paul Reese that the project should be cost efficient. Since a specific budget was not set, plans were designed with the simple mentality of lowering costs wherever possible. Along with this, plans were made to reduce construction. Understanding that the location of the drain system is a busy area, construction would greatly impede the lives of those that frequent the area. Plans were designed to minimize interruption for the community.

Since there is already an existing storm drain system, it would be ideal to use a lot of the system that is already in place. Along with this idea, the plans were to fit the already existing contours of the area. Major excavation or elevation changes would be difficult and disruptive to the community.

One method of storm water management that was not to be used was the deep street-side gutter. Although they are common around the area, the safety risks involved are too much to use in this area.

Hydrological Analysis

Hydrological analysis of the watershed affecting the flood zone was performed in order to develop a maximum flow for 25 year and 50 year floods. Analysis was performed using WMS. IDF curves were obtained from Provo City's website and were used to acquire rainfall intensities for 25- and 50-year floods. In WMS we were able to obtain the watershed area by comparing a calibrated surface map to BYU's map of storm drains throughout campus. Runoff coefficients were taken by comparing surface conditions to descriptions of certain runoff conditions in a table from a hydrology textbook.

Values for these parameters were used to calculate a flow using the Rational equation (Equation 1). The total area influencing the flow of the pipe was divided into two watershed areas (Figure 1) that converge in the manhole in the intersection of 1060 N and East Campus Drive because storm drains from either side of East Campus Drive converge at that point. Dividing the area into two watershed areas also helped with accuracy since the watershed conditions are different.

Using the IDF curve in Figure 2, we were able to determine the rainfall intensity for 25- and 50-year floods. These values, along with the areas from Figure 1 and runoff coefficients were input into the Rational equation to give a maximum flow.

Pipe Capacities

Method

Flow rate capacities were calculated using the Hazen-Williams equation (Equation 2). Lengths of pipes, elevation changes, and current pipe sizes were taken from the aerial contour maps and utility maps provided by Paul Reese. Depths of catch basins were measured in the field. Although HDPE is commonly advertised as having a C_w value of 140, a conservative value of 120 was used to account for possible damages or imperfections in the pipe. To measure the change in the energy line for the Hazen-Williams equation, most of the catch basins were assumed to be full to the ground elevation (due to the intense rainfall). If this value gave a negative slope, it was assumed that there was a 6" downward change in elevation to provide some flow.

Current Pipes

Analyzing at the current pipes, it is evident that they are not sized to carry the necessary flow for the parking lot. While we would like flow rate capacities around 50 cfs for the major pipes, the current pipes in the parking lot are often times 8" pipes and have a calculated capacity less than 5 cfs. Even the main pipe on East Campus Drive only has a calculated flow of approximately 20 cfs (Table 1, Map 1).

Design

The proposed plans increase many of the pipe sizes, particularly those at the bottom of the parking lot, so that they can carry the maximum flow. Our emphasis is on pipes where multiple smaller pipes meet so that it can feed into the large pipe on East Campus Drive. Two of the solution alternatives change the 18" pipe on East Campus Drive to a 28" pipe, increasing the flow capacity from approximately 20cfs to 50cfs (Table 1).

Increasing pipe diameters is a common theme throughout the solution alternatives we have provided. The increased flow capacities can be seen in Table 1.

Design Evaluation Criteria

Designs were evaluated based on a variety of criteria. The following were the key criteria, ordered based on importance:

- Storm water removal efficiency
- Cost
- Construction time

After each solution alternative is summarized, an evaluation mainly focused on these criteria is provided.

Solution Alternatives

Three Phase Plan

Summary

This plan is a thorough overhaul of the current storm drain system, but it is divided into three phases for construction flexibility. Each phase progressively increases the effectiveness of the system by increasing the capacity of the system. Dividing the design into three phases provides budget flexibility while also possible spacing of the construction process to avoid prolonged construction times in one area.
This drainage system design is centered on increasing the pipe diameters of the pipe on East Campus Drive and the south end of the parking lot while also installing pipes throughout the parking lot. A map has been provided with the proposed plan (Maps 2-4). The new pipes are to be corrugated HDPE pipes. This type of pipe was selected because of increased flow and ease of construction (Table 2). In discussing the plans with the project sponsor, it also seems that BYU is generally using more HDPE pipe in its projects.

The estimated cost for this plan is $292,600. Materials account for $177,600, labor accounts for $75,000, and the engineering is $40,000. Not including the engineering, Phase 1 costs $76,750, Phase 2 costs $39,850, and Phase 3 costs $136,000.

Phase 1: East Campus Drive Pipe

The calculated flow capacity of the pipe on East Campus Drive is about 22cfs. Unfortunately, the calculated demand for the system is about 50cfs. With this need for an increase, this plan replaces the current 18” pipe with a 28” HDPE pipe (Map 2), increasing the flow capacity to approximately 50cfs (Table 1). Increasing this pipe alone may increase the capacity of the entire system, but there is still concern about the capacity of the pipes leading into this pipe.

Phase 2: Curb Inlet/Trench Drain

A key fault in the current system is the size of the pipes on the south side of the parking lot. At 8”, these pipes do not carry nearly enough storm water. There is also concern about the number of catch basins available for the storm water to enter the pipes. These concerns have been addressed by creating a curb inlet that runs the length of the curb on the south side of the parking lot (Map 3) and goes directly into the trench drain (Curb-Inlet Storm Drain Detail attached). The trench drain is essentially an extended concrete catch basin that will be constructed in the field. This deign increases the capacity by enlarging the cross-sectional area for the flow and increasing the inlet size.

Phase 3: Parking Lot Drain System

To reduce water accumulation as the storm water runs down the parking lot, a pipe system has been designed to collect water throughout the parking lot (Map 4). Extended parking curbs would span the rows of cars (between the two parking spots where the bumpers meet) to catch water and direct it toward the catch basins. Not only will this reduce the amount of water accumulating on the surface before it reaches the curb inlet, it will also provide a small amount of extra storm water storage space.

Benefits

This plan provides a full, thorough plan to prevent future flooding around the Snell Building. It increases capacity in the entire system from the water collection throughout the parking lot pipe on East Campus Drive that leads to the city pipe.

Regarding cost, this plan provides flexibility for any short term budget constraints. The phases can be completed as funding arrives, reducing the possible impact of one large cost.

This phase system also allows for divided construction times. If there are certain times of the year with reduced traffic, each phase could be completed during those separate times.

Possible Problems

The total cost of this project is higher than preferred (Table 3). Considering the amount of pipe being added to the parking lot, this system is thorough but expensive. A lot of money can be saved by only completing Phase 1 and Phase 2, but adding Phase 3 dramatically increases the cost.
Also, although the construction can be spread out to convenient times, it still requires construction on high traffic roads. A system that avoids this entirely would be preferred.

Storm Water Tank

Summary

The storm water tank is designed to collect the water and hold it while slowly allowing the water into the pipe system. This tank would likely be a 100,000 gallon tank placed in the northeast corner of the smaller parking lot north of the Snell Building. This provides a location near the main collecting pipes that also does not have any utilities running through it. All the pipes that currently meet at the street intersection will be redirected to the tank so that it functions as a primary intersection. From there, it can empty into the East Campus Drive pipe at a flow rate that it can carry.

Benefits

This plan can efficiently store water so that the East Campus Drive pipe does not overflow. There is also a possibility that the City of Provo will require storm water storage tanks in the near future, so this could be a preemptive project to prepare for that requirement.
A key benefit of this option is avoiding major construction in the area. Although some pipes need to be angled differently from the intersection to the tank, the primary construction takes place away from the major traffic in the smaller parking lot. This would allow for regular traffic flow through the area during construction.

Possible Problems

While this allows for a place for the water to go, it does not provide a clear path for the water to reach the pipe. Storm water may still be backed up in the pipes leading to the tank and/or accumulating on the surface before it reaches pipes.

The tank option may also lead to increased prices due to the possible need of a customized tank for the open area available.

Alternate Parking Lot Pipe System

Summary

This plan is the same as the Three Phase Plan, but with an adjustment to the third phase. Instead of the parking lot pipes running primarily north-south, the pipes run east-west. This routes a majority of the water into a pipe running along the side of the Law Building and then down toward the main intersection. Such a system would require the parking lot to be repainted with the lanes going east-west. This change would allow the water to be directed with parking curbs running with the rows of cars to direct the water into catch basins located along the curbs.

Benefits

This pipe system would direct the water toward and already-existing 12” pipe near the Law Building, which would then lead to the main intersection. This would create two routes for the water to reach the East Campus Drive Pipe (the pipe system and the trench drain). The duality of routes avoids flooding if one pipe is full of debris or is one begins to overflow.

Possible Problems

This system is only plausible is the parking lot is repainted to create the rows of cars in the other direction. Such a change is worth considering when deciding on a plan.

Costs and construction considerations are the same as Phase 3 of the Three Phase Plan.

Conclusion

Considering the criteria for evaluating the possible options, we recommend the Three Phase Plan for the storm drain system. The efficiency and cost/construction flexibility make it the best option presented. In reality, the storm drain system could fail in a variety of ways. The flow could get backed up in the East Campus Drive pipes, the pipes at the south end of the parking lot, the inlets into the pipes, or by accumulating on the ground surface before it reaches the pipes. While the tank system addresses the first possible mode of failure, it leaves the rest as possible problems. The Three Phase Plan makes changes to provide the flow capacity necessary in all areas to ultimately prevent any flooding in the area.

Appendix A: Figures

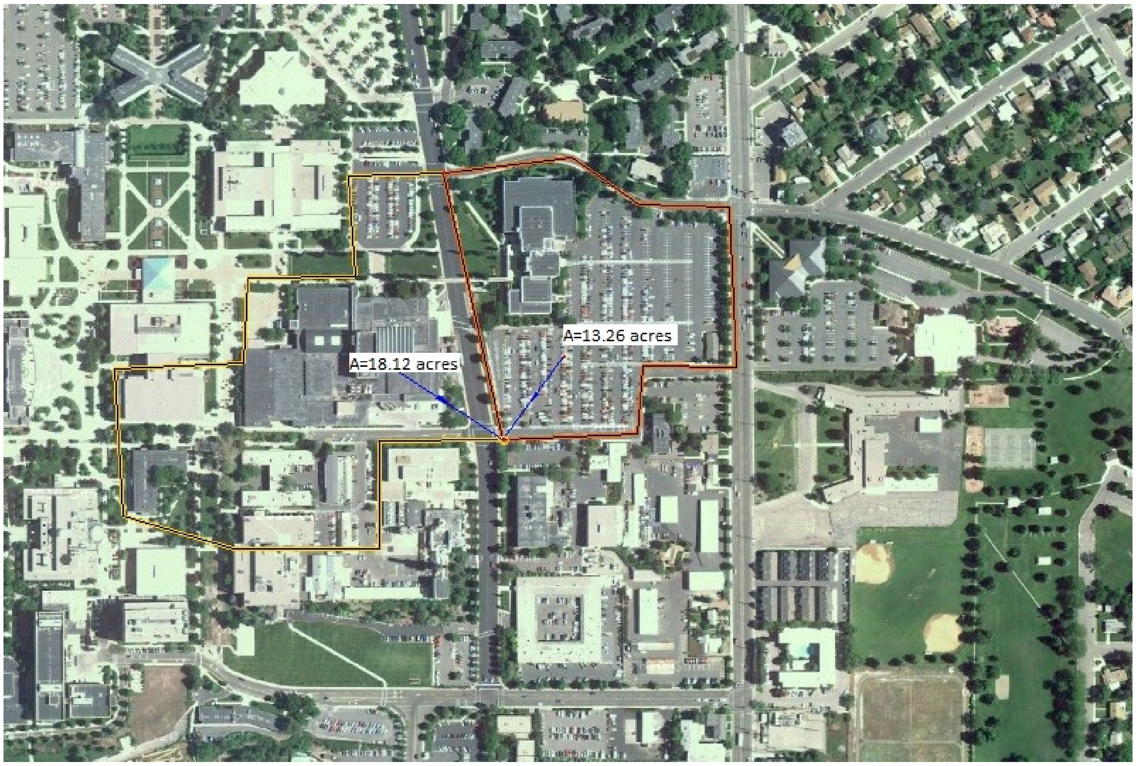


Figure 1 - Delineation of the watershed and the areas associated with watersheds on either side of Campus Drive.

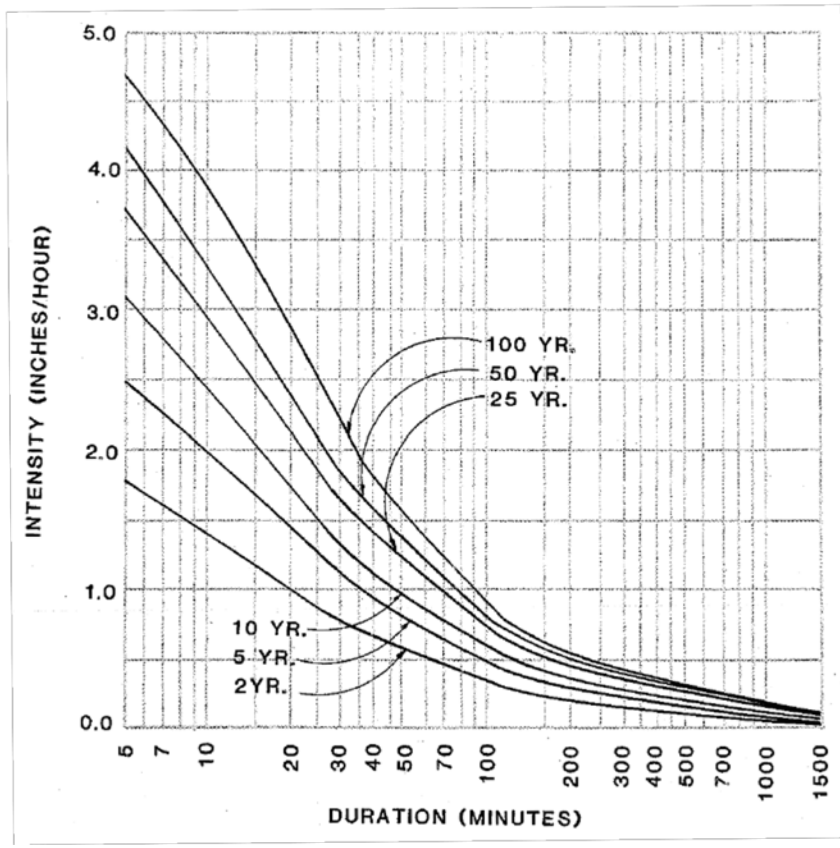


Figure 2 - Provo City Rainfall Intensity-Duration-Frequency Curve

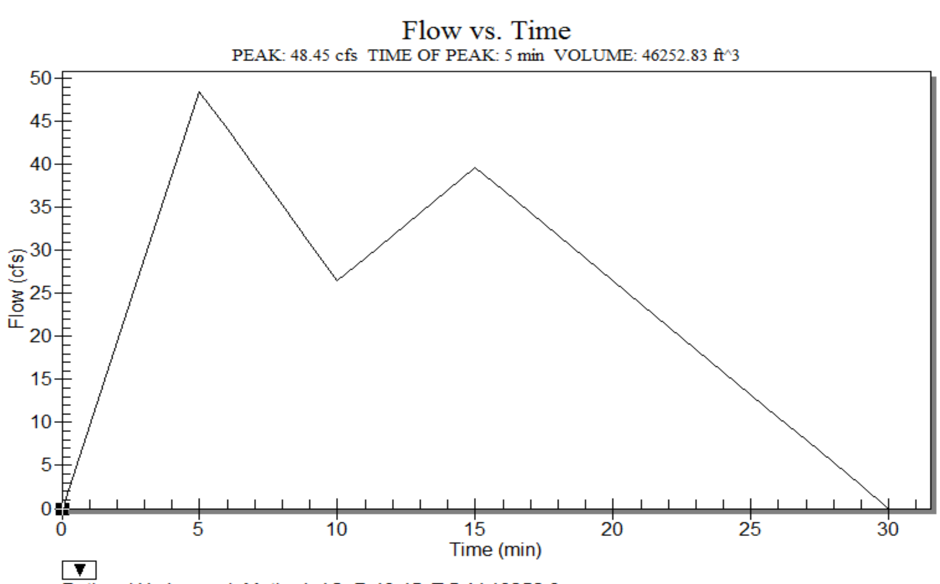


Figure 3: Rational Hydrograph

Appendix B: Equations

Equation 1 – The Rational equation

$$Q = CiA$$

Q - flow

C - runoff coefficient

i - intensity

A – area

Equation 2 - Hazen-Williams equation

$$Q = 1.32 C_w A R^{0.63} {S_e}^{0.54}$$

C_w – Hazen-Williams roughness coefficient

A – Cross-sectional area of pipe

R – Hydraulic radius

S_e – Energy slope line

Appendix C: Tables

Table 1 - Pipe capacities. Refer to maps for pipe locations.

Pipe Name	Catch Basin # (start)	Catch Basin # (end)	C_w	Dia. (in)	Flow rate (Q) (ft^3/s)	Flow rate (Q) (gal/min)	Notes
A	1	2	120	8	2.98	23.92	Current pipe
B	2	3	120	8	2.25	18.02	Current pipe
C	3	4	120	8	1.49	11.98	Current pipe
D	4	5	120	8	2.50	20.07	Current pipe
E	5	6	120	8	2.75	22.02	Current pipe
F	6	7	120	12	7.22	57.92	Current pipe
G	7	8	120	12	10.84	86.92	Current pipe
H	9	8	120	8	2.96	23.74	Current pipe
I	10	19	120	8	3.94	31.62	Current pipe
J	9	10	120	8	2.49	20.01	Current pipe
K	11	10	120	8	1.89	15.15	Current pipe
L	14	9	120	8	3.77	30.26	Current pipe
M	13	14	120	8	2.08	16.67	Current pipe
N	18	13	120	8	3.65	29.31	Current pipe
O	16	18	120	8	1.99	15.93	Current pipe
P	17	16	120	8	2.47	19.85	Current pipe
Q	8	12	120	18	22.05	176.84	Current pipe
R	12	15	120	18	15.16	121.60	Current pipe
S	9	8	120	18	24.98	200.36	Curbside Canal Option
T	8	12	120	28	70.47	565.25	Proposed E Campus Dr pipe
U	12	15	120	28	48.46	388.69	Proposed E Campus Dr pipe
V	23	24	120	8	3.22	25.80	Full Parking Lot - Current set-up
W	25	26	120	8	3.45	27.67	Full Parking Lot - Current set-up
X	27	28	120	10	4.56	36.54	Full Parking Lot - Current set-up
Y	28	29	120	10	4.67	37.44	Full Parking Lot - Current set-up
Z	30	31	120	10	4.50	36.08	Full Parking Lot - Current set-up
AA	16	13	120	12	10.27	82.35	Full Parking Lot - Current set-up
BB	13	14	120	18	17.54	140.68	Not used
CC	14	8	120	18	26.44	212.08	Not used
DD	32	33	120	8	3.01	24.15	Full Parking Lot - Redo
EE	33	34	120	8	1.77	14.19	Full Parking Lot - Redo
FF	34	37	120	10	4.09	32.78	Full Parking Lot - Redo
GG	35	36	120	8	3.19	25.60	Full Parking Lot - Redo

HH	36	37	120	8	1.44	11.59	Full Parking Lot - Redo
II	37	6	120	12	5.71	45.79	Full Parking Lot - Redo
JJ	6	38	120	12	5.35	42.93	Full Parking Lot - Redo
KK	38	7	120	18	23.59	189.19	Full Parking Lot - Redo
LL	7	8	120	18	31.48	252.48	Full Parking Lot - Redo
MM	9	8	120	18	24.98	200.36	Full Parking Lot - Redo
NN	13	9	120	12	7.55	60.53	Not used
OO	28	38	120	10	4.17	33.46	Full Parking Lot - Redo
PP	26	28	120	10	6.13	49.20	Full Parking Lot - Redo
QQ	7	9	120	12	8.88	71.25	Tank option
RR	20	9	120	22	25.16	201.82	Tank option
SS	39	22	120	26	30.82	247.21	Tank option
TT	21	19	120	18	24.10	193.33	Tank option
UU	22	21	120	26	80.37	644.64	Tank option

Table 2 - Pipe Material Analysis

<table>
<tr><th>Material</th><th>Concrete</th><th>PVC</th><th>Corrugated HDPE</th><th>Smooth HDPE</th></tr>
<tr><td>Manning's n Value</td><td>0.012</td><td>0.009-0.011</td><td>0.018-0.025</td><td>0.009-0.015</td></tr>
<tr><td>Hazen-Williams Coeff.</td><td>100-140</td><td>130-150</td><td></td><td>140</td></tr>
<tr><td>Temp Range</td><td></td><td>32-140</td><td colspan="2">-180<</td></tr>
<tr><td>Damage Resistance</td><td>+++</td><td>++</td><td colspan="2">++</td></tr>
<tr><td>Structural Strength</td><td>+++</td><td>++</td><td colspan="2">+</td></tr>
<tr><td>Cost</td><td>+++</td><td>++</td><td colspan="2">+</td></tr>
<tr><td>Pressure Rating</td><td></td><td>+++</td><td>++</td><td></td></tr>
<tr><td>Algae Resistance</td><td>+</td><td>+++</td><td colspan="2">+++</td></tr>
<tr><td>Lifespan</td><td>+++</td><td>+++</td><td>+++</td><td></td></tr>
</table>

Table 3 - Costs for the Three Phase Option

Three Phase Option				Costs		Costs		Hours	Cost	Total
Phase 1	28" pipe	790	ft	$ 51,350.00	Connections:	$ 400.00	Work Hours:	500	$ 25,000.00	$ 76,750.00
Phase 2	18" pipe	115	ft	$ 5,750.00		$ 300.00		250	$ 12,500.00	$ 39,850.00
	Curbside catch basin	140	ft	$ 21,000.00		$ 300.00				
Phase 3	8" pipe	600	ft	$ 21,000.00		$ 300.00		750	$ 37,500.00	$ 136,000.00
	10" pipe	650	ft	$ 24,700.00		$ 600.00				
	12" pipe	250	ft	$ 10,000.00		$ 600.00				
	18" pipe	120	ft	$ 6,000.00		$ 600.00				
	22" pipe	220	ft	$ 12,100.00		$ 1,000.00				
	Std. curb catch basins	9		$ 21,600.00		-				
			Sum	$ 173,500.00		$ 4,100.00			$ 75,000.00	
					Engineering Tot.:	$ 40,000.00				
					Total	$ 292,600.00				

Appendix D: Maps and Details

Maps with markings corresponding to the values in Table 1 have been attached, along with the detail for the Curb-Inlet Storm Drain.

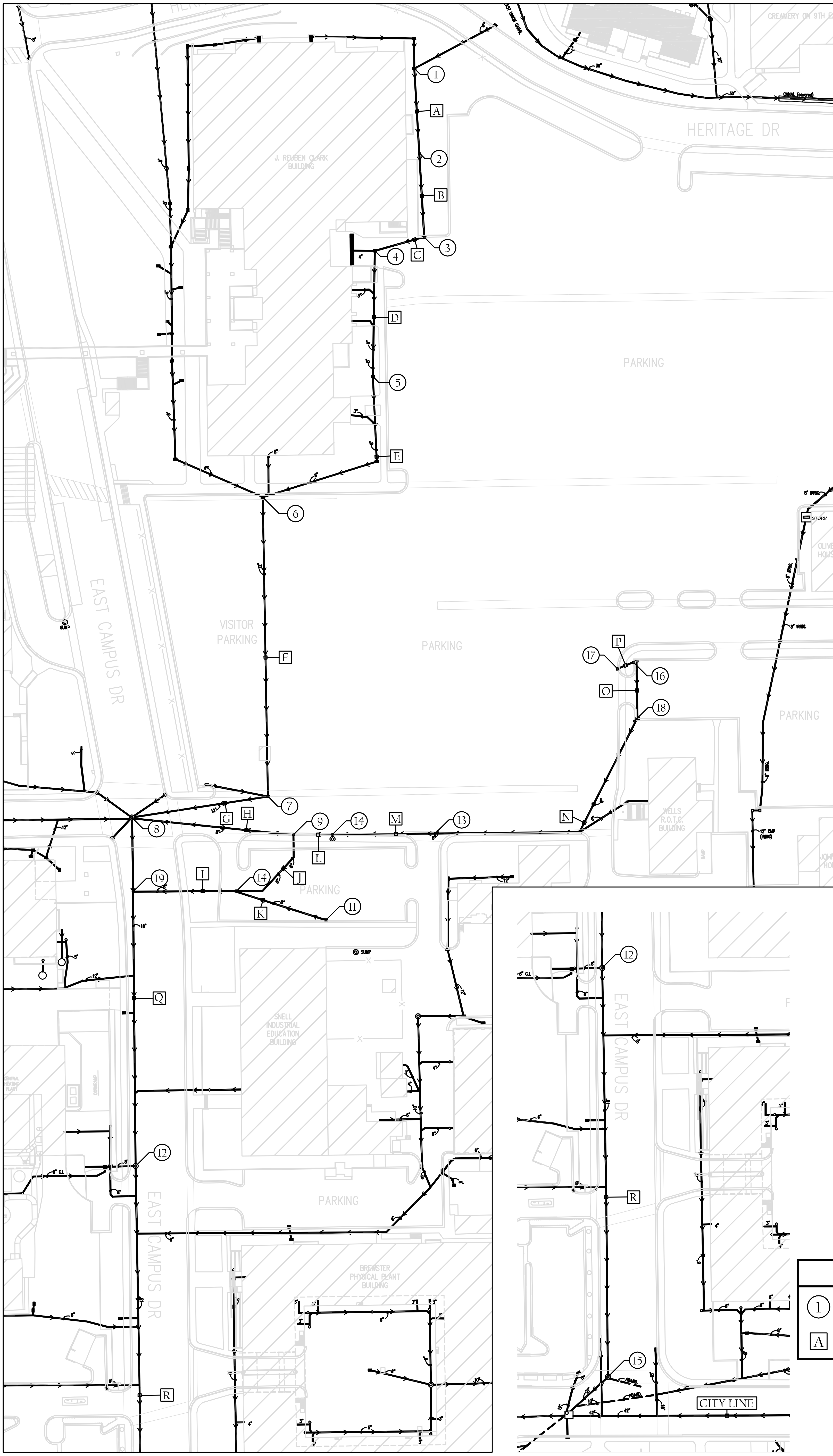
Map 1: Existing Storm Sewer Layout

Map 2: New Storm Drain – Design 1 Phase 1

Map 3: New Storm Drain – Design 1 Phase 2

Map 4: New Storm Drain – Design 1 Phase 3

Curb-Inlet Storm Drain Detail



N

LEGEND

1	STORM DRAIN IDENTIFIER
A	PIPELINE IDENTIFIER

SHEET 1 of 4

DATE 4-9-12

SCALE 1/8" = 1'-0"

DRAWN BY BYU/AJV

EXISTING STORM SEWER LAYOUT

BRIGHAM YOUNG UNIVERSITY

SNELL BLDG & LAW SCHOOL PARKING LOT FLOODING

CEEn 472 - CE DESIGN

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SHEET 2 of 4

DATE 4-9-12

SCALE 1/8" = 1'-0"

DRAWN BY BYU/AJV

NEW STORM DRAIN - DESIGN 1 PHASE 1

BRIGHAM YOUNG UNIVERSITY

SNELL BLDG & LAW SCHOOL PARKING LOT FLOODING

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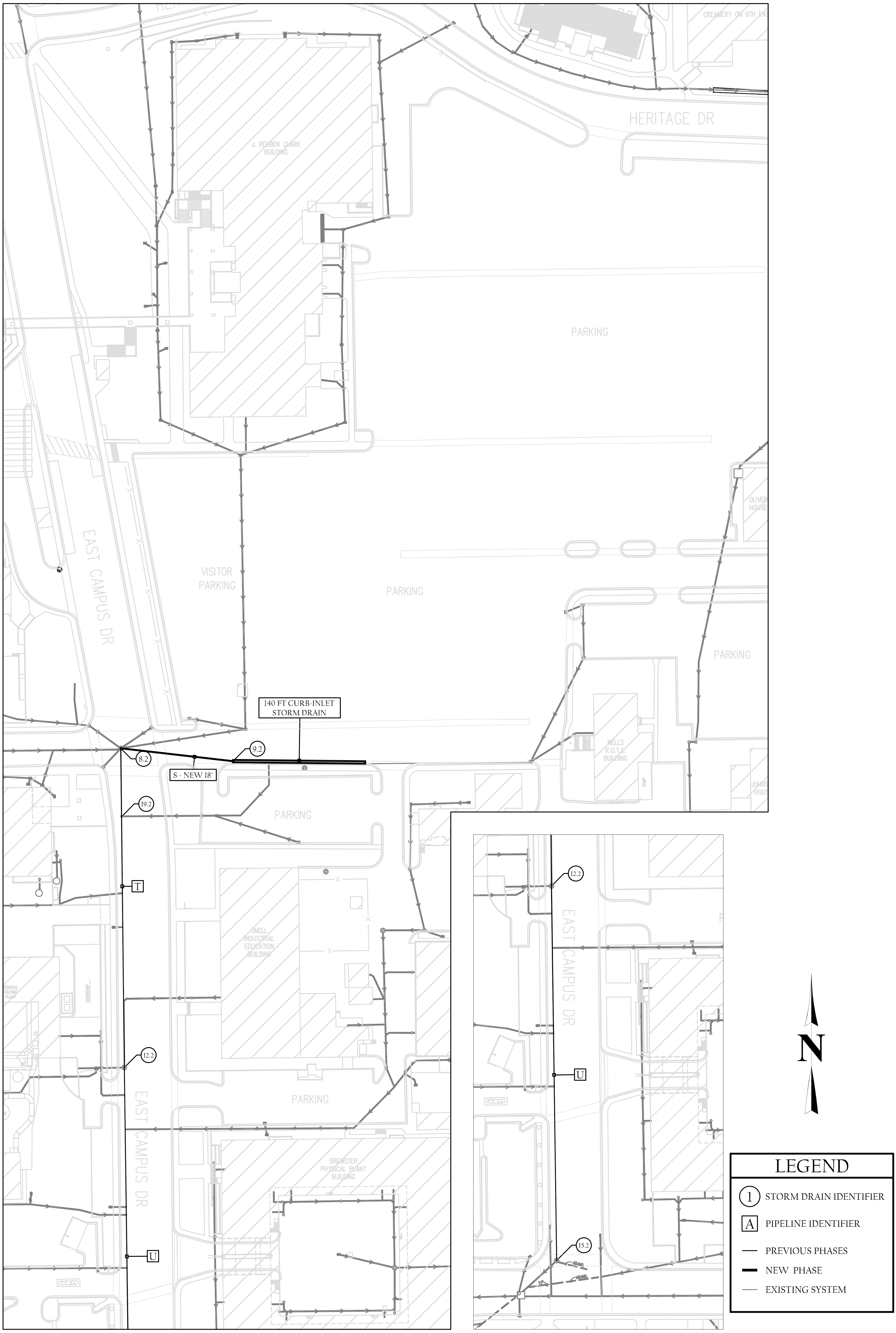

NEW STORM DRAIN - DESIGN 1 PHASE 2

SHEET 3 of 4

DATE 4-9-12

SCALE 1/8" = 1'-0"

DRAWN BY BYU/AJV

BRIGHAM YOUNG UNIVERSITY

SNELL BLDG & LAW SCHOOL PARKING LOT FLOODING

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LEGEND

1	STORM DRAIN IDENTIFIER
A	PIPELINE IDENTIFIER
—	PREVIOUS PHASE
—	NEW PHASE
—	EXISTING SYSTEM

SHEET 4 of 4

DATE 4-9-12

SCALE 1/8" = 1'-0"

DRAWN BY BYU/AJV

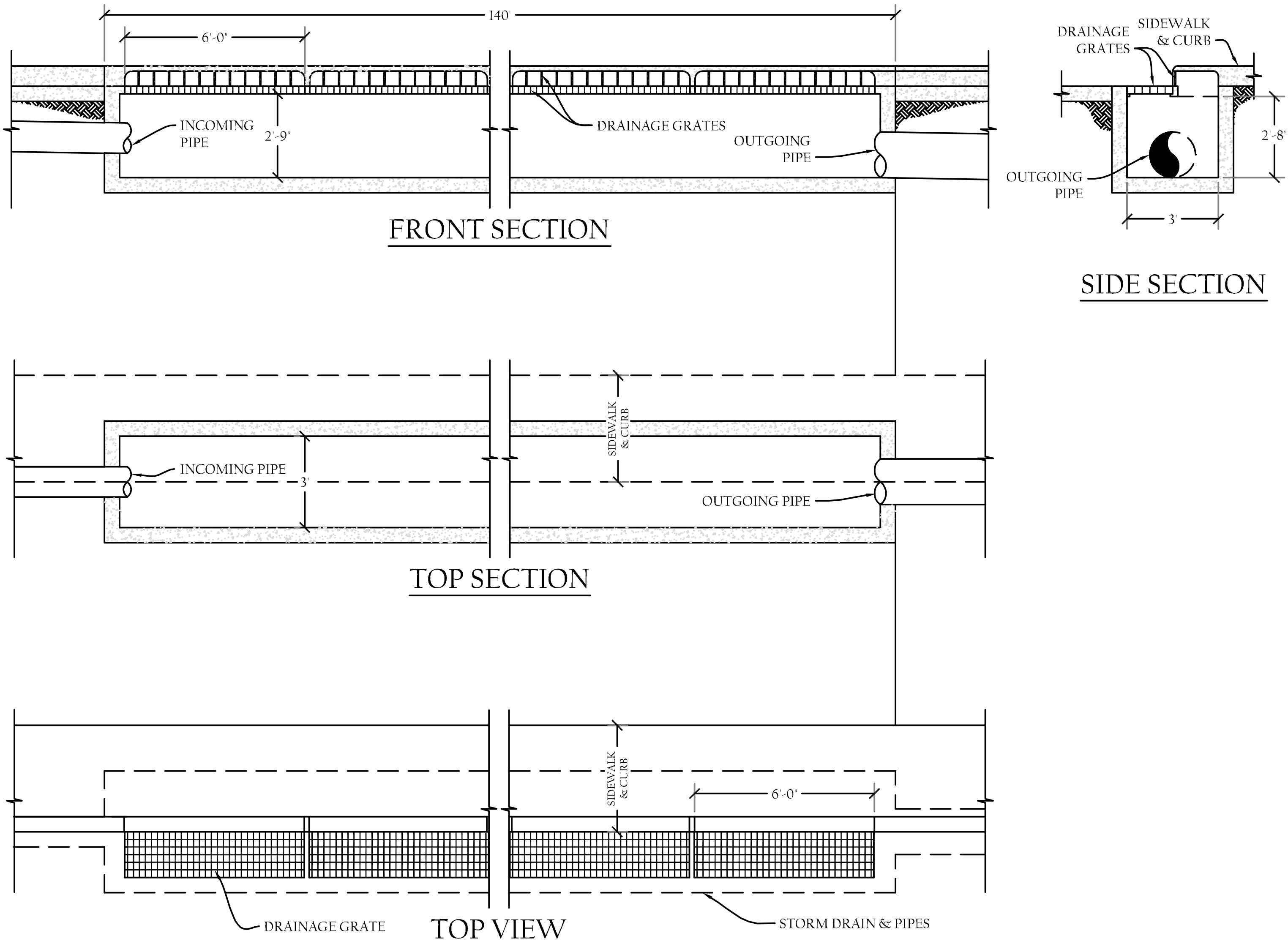
NEW STORM DRAIN - DESIGN 1 PHASE 3

BRIGHAM YOUNG UNIVERSITY

SNELL BLDG & LAW SCHOOL PARKING LOT FLOODING

CEEn 472 - CE DESIGN

YDABT ENGINEERING



Curb-Inlet Storm Drain

YDABT ENGINEERING

BRIGHAM YOUNG UNIVERSITY
SNELL BLDG & LAW SCHOOL PARKING LOT FLOODING
CEEn 472 - CE DESIGN

DATE 4-9-12
SCALE 3/16" = 1'-0"
DRAWN BY AJV

SHEET 1 of 1