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MEMORANDUM

DATE: October 31, 2017

TO: Annabell Ulary, P.E., CFM, City of Austin Watershed Protection Department;
Thuan Nguyen, P.E., CFM, City of Austin Public Works Department

FROM: Travis M. Michel, P.E., CPESC
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SUBJECT: Comparison of 2D Results to 1D Design
LAN Project No. 120-11884-001

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This technical memorandum presents the findings of a comparison of 2D results based on InfoWorks ICM version 6.5 with standard City of Austin 1D design methods using StormCAD V8i. Comparisons were made on pipe sizing, peak flows in proposed storm sewer systems, and overall benefits and impacts results.

1.1 Pipe Sizing

The recommended solutions for the Oak Knoll Drive and Bell Avenue study areas are shown on Exhibits 2.3 and 4.1 respectively in the preliminary engineering report (PER) dated October 31, 2017. The PER presents the preliminary sizing of the drainage improvements and alternative analyses. Based on the preliminary report, K Friese & Associates (KFA) developed a 30% design of selected alternatives using standard 1D methods defined in the City's Drainage Criteria Manual (DCM) and in the process refined the sizing of the proposed drainage improvements. Table 1 below compares the pipe sizes in the PER alternative analysis and the KFA's 30% design. The 30% plan set is attached to this memorandum.

Table 1. Comparison of Pipe Sizes between PER and 30% Design

Location	PER Recommendations	30% Design
Oak Knoll Area		
Woodcrest Drive	4'x3' RCB	36" RCP to 5'x3' RCB
Broad Oaks Drive	24" RCP	18" to 30" RCP
Oak Knoll Drive	30" RCP	36" RCP
Three Oaks Trail	36" RCP	No proposed pipe
Drainage easement east of Three Oaks Trail	5'x3' RCB	5'x3' RCB
Columbia Oaks Ct	6'x3' RCB	6'x3' RCB
Bell Avenue Area		
Bell Avenue	6'x3' RCB	3'x'3 to 4'x3' to 5'x3' RCB
Secrest Drive	24" RCP	24" RCP

A few notes regarding the 30% design:

Oak Knoll Area

- The existing inlets on the east side of Oak Knoll were not connected to the proposed trunk line. Most of the water will be captured in the new inlets; therefore, the existing trunk line connecting the existing inlets is no longer undersized and will remain in place.
- A trunk line was not proposed along Three Oaks Trail. Instead a single 10' inlet was added to the west side. Due to the improvements on Oak Knoll, the existing system was no longer over capacity.

Bell Avenue Area

- Instead of adding curb and gutter and curb inlets along the east side of Bell Ave, ditch inlets and ditch improvements were proposed along the west side. This reduced the amount of inlets and removed the need for curb and gutter along the east side of the street.
- The trunk line along Secrest Dr was extended north just past the existing curb inlet. It was determined that improving the curb and gutter along the outside bend of Secrest Drive was not sufficient to reduce flooding. Two inlets (15' and 10') were added to reduce bypass flow.

1.2 Peak Flows

StormCAD and the DCM were used for the 1D analysis and peak flows were calculated using the Rational Method. StormCAD uses the link-node approach. The flows are input into the pipe systems through inlets. Where the inlet capacity is exceeded, inlet bypass is simulated to transfer the excess flow to the next downstream inlet. On the other hand, InfoWorks ICM uses 2D dynamic modeling in conjunction with the pipe analysis. Differences in computed peak flows may be due to 1) Inaccuracies in the input data; 2) modeling methods; and/or 3) modeling techniques/assumptions. Detail discussion for each one of these categories is presented below.

1) <u>Inaccuracies in the input data</u> - Engineering interpretation of drainage divides and the inability to account for flow between subareas is a limitation in traditional 1D analyses. For retrofit situations, this inaccuracy may be significant since the designer does not have control of the grading of the area as in a new development. 2D methods such as rain on mesh (ROM) can utilize the terrain surface to account for flow between subareas. However, the terrain surface (LiDAR) may lack sufficient detail to always accurately represent drainage patterns. The addition of grade breaks and storm drain infrastructure to the 2D model can improve the simulation; however, the addition of detail can take additional time and money to integrate and may or may not improve the study. Similarly, flow paths and times of concentration are simplified for use in 1D methods whereas 2D ROM is more comprehensive in simulating runoff. Both 1D and 2D models may have inaccuracies; however, with sufficient effort and detail, 2D models can reduce those inaccuracies and yield a more robust model for conducting analyses and assessing benefits. Traditional 1D methods can provide a baseline for comparison to identify and correct for inaccuracies if appropriate.

2) <u>Modeling Methods</u> - There are a number of differences between the modeling methods that contribute to differences in computed flows and hydraulic grade lines:

a. ROM simulations allow for cross basin transfer while the Rational Method assumes rigid boundaries. For example, in 1D analyses, the centerline of a crowned street is typically assumed to be the flow divide. But in 2D, flows can cross over from one side of the road to the other side.
b. The rainfall intensity in the Rational Method is a function of Tc. There is some judgment in the calculation of Tc. Different estimates of Tc give different flow rates. On the other hand, ROM removes the need for such judgment.
c. ROM explicitly accounts for depression storage whereas the Rational Method does not simulate depression storage. If the modeler knows that a particular area has significant depression storage, the runoff coefficient may be adjusted to account for that. However, unless calibration is done, the adjustment is basically a judgment call.
d. Moreover, the dynamic simulation in ICM accounts for storage in the pipes, the timing of hydrographs when flows from different pipes come together, and also allows reverse flows in pipes.
e. StormCAD uses standard steady state calculations for the hydraulic grade line while ICM solves the St. Venant equations. Moreover, in this analysis the head losses in ICM were calculated using default settings. In the StormCAD model, head losses were calculated following the DCM.

3) <u>Modeling techniques/assumptions</u>

a. Infiltration was not utilized within the ICM model. The study area has relatively high impervious cover and the hydrologic soil group is Type D which has low infiltration potential. As discussed in the PER, the ICM flows are close to flows calculated using HEC-HMS which has accounted for losses using the curve number method. The Rational Method uses a composite runoff coefficient which is an area-weighted average of the runoff coefficients of the pervious and impervious areas. The impervious areas were based on the planimetrics for each subarea. The runoff coefficient in Table 2-1 of the DCM is a function of surface characteristics but does not account for soil type. As a result of these modeling assumptions, one would expect the Rational Method flows to be more sensitive to impervious cover percentage.
b. The StormCAD 1D analysis assumed the tailwater to be at the soffit of the terminal pipe of each system. In the ICM model the hydraulic grade at that location is itself a result of the simulation of the broader 2D domain. The tailwater conditions of the systems being designed were higher in the ICM model than in the 1D analysis. At Bell Avenue, the downstream end of the drainage improvements connects to an existing 6’x3’ RCB of the US 183 storm sewer system which is probably not designed for the COA 25-yr or 100-yr storms. Therefore, the ICM model shows that the proposed system is backed up under these large storm events.
c. The way inlets are modeled is another reason for differences in flows. In the 1D analysis, the Rational Method flows are either put in the pipes or transfer between inlets where the inlet capacities are exceeded. On the other hand, in the ICM model the flows follow the terrain and are captured by 2D nodes into the pipe system. The amount of capture depends on the local terrain and the parameters set at the 2D nodes.

In this analysis, LAN developed updated 2D PER models to correspond to the 30% design prepared by KFA for selected alternatives for comparison of computed peak flows as shown in Tables 2 and 3 for the Oak Knoll and Bell Avenue areas respectively. It is noted that the pipe sizes in the Oak Knoll ICM model were based on an earlier version of the 30% design in which the 5’x3’ RBC along Woodcrest and the drainage easement was 4’x3’.

This change in the 30% design was made when the ICM analysis was substantially completed. Since it was not expected to have a significant effect on the model results and evaluation, the ICM analysis was not revised with the new pipe size.

For both study areas, a main reason for the difference in flow in the downstream area of each system is the different tailwater conditions as noted above. The effect of the tailwater condition is more pronounced for the 100-year event. The effect of the tailwater dissipates going upstream.

Another factor includes the difference in flows as calculated by the Rational Method and ROM. At the upstream end of the proposed system in the Bell Avenue area, the 1D analysis assumed all the flow from the drainage area south of Jollyville Road to enter the proposed system. However, in the ICM model, there is a significant amount of sheet flow across Jollyville Road (at the peak, about 47 cfs for 25-yr and 76 cfs for 100-yr). Some of this flow is captured by the proposed inlets along Bell Avenue into the proposed system, but a significant amount of this flow drain toward the Covert car dealership area and does not enter the proposed system. Even though at the upstream end the ICM model has smaller 25-yr flow than the StormCAD model, proceeding downstream the flow in the ICM model becomes higher, indicating that overall the runoff computed by the ICM model is higher than that computed by the Rational Method. For the 100-yr event, the ICM flow is lower from the upstream end of Bell Avenue all the way to the downstream end. That is because in the ICM model a significant amount of the flow from south of Jollyville Road is not captured by the system.

1.3 Benefits and Impacts

The benefits to the project areas are depicted in Exhibits 1 and 2 for the Oak Knoll area and Bell Avenue area, respectively. Tables 4 and 5 compare the benefits resulting from the PER and 30% designs in the 100-year event. The ICM model for the Oak Knoll area includes a proposed detention pond downstream of the 6’x3’ outfall. It is noted that the 36” RCP upstream of Broad Oaks Drive in the 30% design was removed in this analysis (see Exhibit 1) due to the added potential for impacts downstream. Runoff currently leaves the project area at the Broad Oaks/Woodcrest intersection. The PER and 30% designs appear to give similar result. The total number of houses removed and helped are the same in each area for both PER and 30% design. The same is true for the number of yards helped. In the Oak Knoll area, the benefit to one house is changed from helped in the PER to removed from 100-yr flooding in the 30% design. But in the Bell Avenue area, one house is changed from removed from the 100-yr flooding in the PER to helped in the 30% design.

Exhibits 3 and 4 show the 100-yr hydrologic impacts of the 30% design for the Oak Knoll area and Bell Avenue area respectively. For Oak Knoll, the impacts for the scenarios with and without detention are shown. The corresponding impacts of the PER design are shown in Exhibits I-1 and I-4 in the PER. The increases in water surface elevation (WSE) and peak flow of the PER and 30% designs are compared in Tables 6 and 7. The changes in WSE and peak flow at the points of interests are generally similar between the PER and the 30% designs. In the with pond scenario, the PER design results in a slightly lower flow in the pipe under Jollyville Road but an increase in flow over the road. On the other hand, the 30% design results in an increase in flow in the pipe but a decrease in flow over the road. The PER design for the Bell Avenue area results in a lower peak flow in Walnut Creek Trib. 7 whereas the 30% design results in an increase.

2.0 Summary and Conclusions

The results presented in the preliminary engineering report (PER) are consistent with the results of the updated analyses based on the 30% design prepared by KFA. Furthermore, the estimated benefits and hydrologic impacts are consistent which provide confidence in the methodology utilized in the PER to derive recommended solutions for planning purposes.

Table 2. Comparison of Peak Discharges between 1D (StormCAD) and 2D (InfoWorks ICM) Analyses for the Oak Knoll Area

LOCATION	LINK ID	PIPE SIZE	25-YR DISCHARGE (CFS)			100-YR DISCHARGE (CFS)		
			StormCAD	ICM	% diff	StormCAD	ICM	% diff
Woodcrest Dr	A-1-01	36" RCP	35.9	35.5	1%	44.8	44.9	0%
	A-1.01	36" RCP	35.9	35.5	1%	44.8	44.8	0%
	A-1.02	36" RCP	35.8	35.5	1%	44.7	44.7	0%
	A-1.03	36" RCP	42.3	46.0	-8%	54.0	64.2	-16%
	A-1.04	36" RCP	60.5	58.1	4%	80.5	82.9	-3%
	A-1.05	36" RCP	61.3	62.1	-1%	81.7	90.8	-10%
	A-1.06	36" RCP	64.7	66.5	-3%	86.4	98.6	-12%
	A-1.07*	5' x 3' RBC*	98.4	94.1	5%	136.0	117.6	16%
	A-1.08*	5' x 3' RBC*	100.2	95.7	5%	138.8	120.1	16%
	A-1.09*	5' x 3' RBC*	100.0	95.7	4%	138.5	120.1	15%
	A-1.10*	5' x 3' RBC*	99.4	95.7	4%	137.7	120.1	15%
	A-1.11*	5' x 3' RBC*	99.3	95.7	4%	137.6	120.1	15%
Easement	A-1.12*	5' x 3' RBC*	101.3	98.3	3%	140.4	121.3	16%
	A-1-13*	5' x 3' RBC*	115.2	113.0	2%	157.2	137.5	14%
Columbia Oaks Ct	A-1.13	6' x 3' RBC	134.3	156.2	-14%	185.0	191.6	-3%
	A-1.14	6' x 3' RBC	134.3	156.2	-14%	184.9	191.6	-3%
	A-1.15	6' x 3' RBC	134.2	156.1	-14%	184.8	191.7	-4%
	A-1.16	6' x 3' RBC	133.8	156.0	-14%	184.3	191.9	-4%
	A-1.17	6' x 3' RBC	133.3	156.0	-15%	183.3	192.3	-5%
	A-1.18	6' x 3' RBC	158.9	148.0	7%	220.9	179.2	23%
	A-1.19	6' x 3' RBC	162.9	160.6	1%	226.9	185.3	22%
Existing (east of Columbia Oaks)	A-1.20	6' x 3' RBC	162.9	160.5	1%	226.8	189.8	19%
	A-1.21	6' x 3' RBC	163.1	160.5	2%	227.1	189.8	20%
	A-1.22	6' x 3' RBC	163.9	168.1	-2%	228.2	203.2	12%
	A-1.22.1	6' x 3' RBC	166.3	173.7	-4%	231.0	186.9	24%
	A-1.23	6' x 3' RBC	166.2	173.7	-4%	230.9	185.1	25%
	A-1.24	6' x 3' RBC	166.3	188.5	-12%	231.3	199.3	16%
	A-1.25	6' x 3' RBC	166.2	188.5	-12%	231.2	196.9	17%
	A-1.26	6' x 3' RBC	165.3	188.5	-12%	229.9	196.9	17%
Broad Oaks Drive	A-2.1	18" RCP	2.7	0.5	436%	3.6	0.8	351%
	A-2.2	18" RCP	7.3	7.0	4%	9.8	8.8	11%
	A-2.3	24" RCP	12.7	9.9	28%	17.8	13.0	37%
	A-2.4	24" RCP	15.4	12.9	19%	22.1	16.2	36%
	A-2.5	24" RCP	16.5	15.1	9%	23.9	18.8	27%
	A-2.6	30" RCP	18.5	16.2	14%	26.8	19.9	35%
Oak Knoll Drive	A-3.1	36" RCP	31.2	24.8	26%	46.3	28.1	65%
	A-3.2	36" RCP	35.2	29.8	18%	51.8	34.6	50%
	A-3.3	36" RCP	34.8	29.7	17%	51.2	34.4	49%
Existing between Oak Knoll and easement	A-3-01	24" RCP	4.4	24.3	-82%	6.0	28.8	-79%
	A-4-01	27" RCP	14.1	33.9	-58%	20.7	39.3	-47%
	A-4-02	30" RCP	21.0	45.8	-54%	30.6	55.1	-44%
	A-4-02.1	30" RCP	20.9	45.3	-54%	30.5	55.1	-45%

* Actual pipe size analyzed in ICM is 4’x3’. See explanation in text.

Table 3. Comparison of Peak Discharges between 1D (StormCAD) and 2D (InfoWorks ICM) Analyses for the Bell Avenue Area

LOCATION	LINK ID	PIPE SIZE	25-YR DISCHARGE (CFS)			100-YR DISCHARGE (CFS)		
			StormCAD	ICM	% diff	StormCAD	ICM	% diff
Bell Avenue	B-1-02	3' x 3' RBC	73.1	54.5	34%	107.2	59.8	79%
	B-1.01	3' x 3' RBC	73.1	54.5	34%	107.2	59.6	80%
	B-1.02	3' x 3' RBC	79.7	61.2	30%	116.7	68.9	69%
	B-1.03	3' x 3' RBC	79.7	61.2	30%	116.6	68.9	69%
	B-1.04	3' x 3' RBC	82.0	80.6	2%	119.9	87.0	38%
	B-1.05	3' x 3' RBC	81.9	80.6	2%	119.8	87.0	38%
	B-1.06	3' x 3' RBC	81.9	81.4	1%	119.8	87.0	38%
	B-1.07	4' x 3' RBC	82.5	81.6	1%	120.6	81.1	49%
	B-1.08	4' x 3' RBC	82.3	81.8	1%	120.5	81.3	48%
	B-1.09	4' x 3' RBC	93.2	94.0	-1%	136.4	93.9	45%
	B-1.10	4' x 3' RBC	93.1	93.9	-1%	136.3	93.9	45%
	B-1.11	5' x 3' RBC	98.4	104.1	-5%	144.2	104.9	38%
	B-1.12	5' x 3' RBC	98.3	104.2	-6%	144.1	105.0	37%
	B-1.13	5' x 3' RBC	97.9	104.2	-6%	143.8	105.0	37%
	B-1.14	5' x 3' RBC	99.7	114.4	-13%	146.6	120.0	22%
	B-1.15	5' x 3' RBC	99.5	114.4	-13%	146.3	119.9	22%
	B-1.16	5' x 3' RBC	103.6	120.5	-14%	152.4	126.8	20%
	B-1.17	5' x 3' RBC	124.2	144.1	-14%	181.3	159.5	14%
	B-1.18	5' x 3' RBC	124.1	144.1	-14%	181.2	159.5	14%
	B-1.19	5' x 3' RBC	123.7	144.0	-14%	180.9	159.5	13%
	B-1.20	5' x 3' RBC	128.9	149.0	-14%	188.8	150.4	26%
	B-1.21	5' x 3' RBC	128.7	149.0	-14%	188.6	150.4	25%
	B-1.22	5' x 3' RBC	128.6	149.1	-14%	188.5	150.5	25%
	B-1.23	5' x 3' RBC	128.6	149.1	-14%	188.4	150.6	25%
	B-1.24	5' x 3' RBC	128.5	149.3	-14%	188.4	150.7	25%
	B-1.25	5' x 3' RBC	130.3	129.4	1%	191.0	130.3	47%
Secrest Drive	B-2.01	24" RCP	12.5	12.9	-3%	16.8	16.7	0%
	B-2.02	24" RCP	12.5	12.9	-3%	16.7	16.7	0%
	B-2.03	24" RCP	12.4	12.9	-4%	16.6	16.7	-1%
	B-2.04	24" RCP	14.0	15.1	-7%	18.8	19.4	-3%
	B-2.05	24" RCP	19.0	19.4	-2%	25.2	25.2	0%
	B-2.06	24" RCP	18.9	19.4	-3%	25.1	25.2	0%
	B-2.07	24" RCP	22.0	24.6	-11%	29.7	32.0	-7%
	B-2.08	24" RCP	22.7	26.4	-14%	31.3	34.2	-8%

Table 4. Benefits in Oak Knoll Area

100-yr			PER		30% Design	
Benefits	**Reported Flooding**	**Flooding Identified in 2D Model**	**Removed**	**Helped**	**Removed**	**Helped**
Buildings	12	6	6	9	7	8
Yard	8	-	0	6	0	6

Table 5. Benefits in Bell Avenue Area

100-yr			PER		30% Design	
Benefits	**Reported Flooding**	**Flooding Identified in 2D Model**	**Removed**	**Helped**	**Removed**	**Helped**
Buildings	5	9	8	4	7	5
Yard	3	-	0	2	0	2

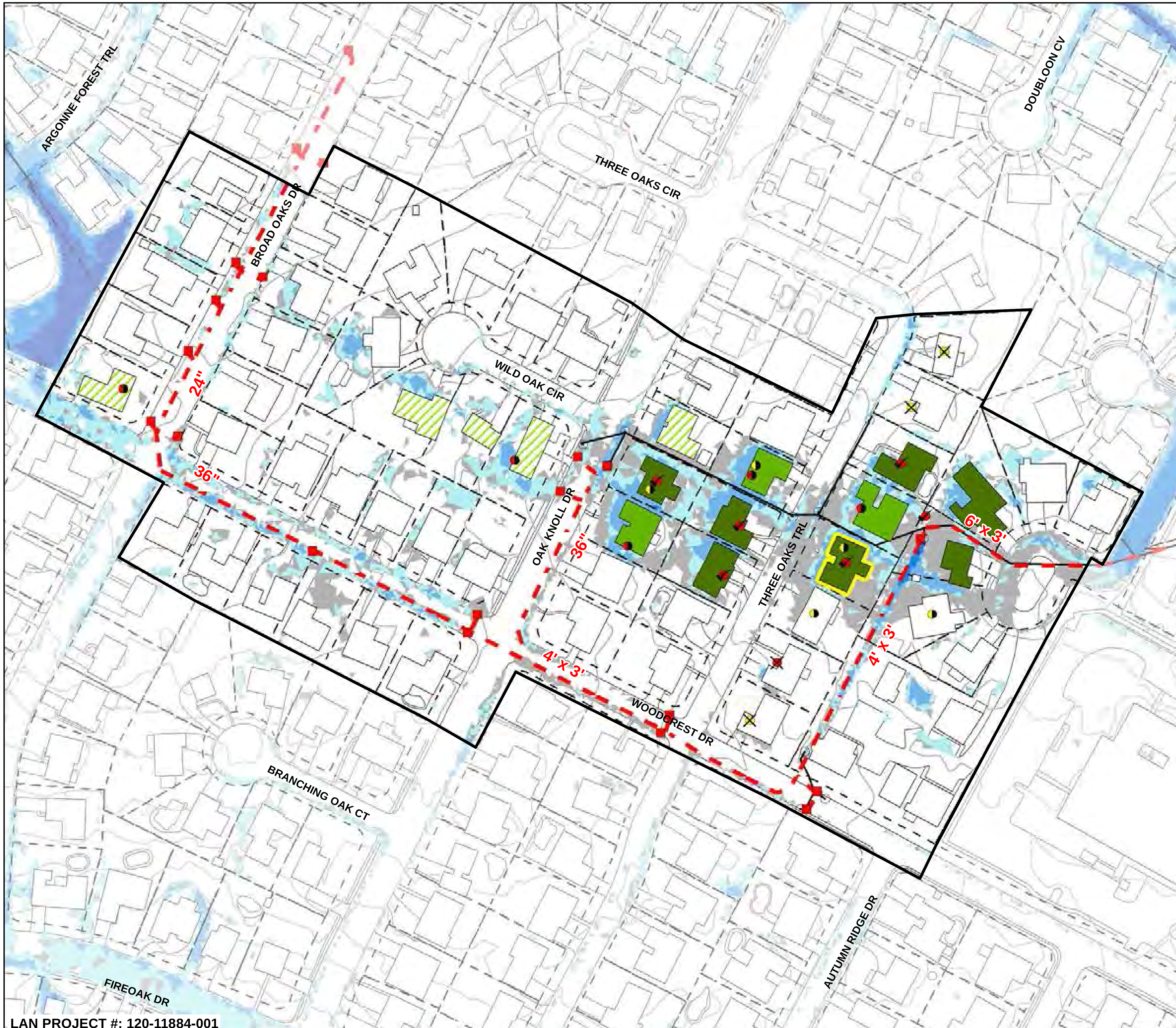
Table 6. Increase in Water Surface Elevation and Peak Flow in Oak Knoll Area

Point of Interest	Increase Proposed w/o Pond		Increase Proposed w/ Pond		Description
	PER	30% Design	PER	30% Design	
Water Surface Elevation (ft)					
1	-0.01	-0.06	-0.26	-0.24	Columbia Oaks Dr Inlet
2	0.12	0.11	-0.40	-0.42	Austin Business Services
3	0.31	0.31	-	-	Driveway d/s outfall pipe*
4	0.49	0.54	0.31	0.13	Ditch along Jollyville Road
Peak Flow (cfs)					
A	4.65	-3.53	-59.51	-56.97	Columbia Oaks Dr
B	57.73	46.43	-	-	Driveway d/s outfall pipe*
C	16.25	9.63	-1.45	9.26	Pipe under Jollyville Road
D	46.39	42.30	13.94	-1.25	Flow over Jollyville Road
E	39.72	15.48	-36.75	-17.25	Walnut Creek Trib. 7

* Ground elevation raised to 903 ft in scenario with detention pond

Table 7. Increase in Water Surface Elevation and Peak Flow in Bell Avenue Area

Point of Interest	Increase		Description
	PER	30% Design	
Water Surface Elevation (ft)			
1	0.54	0.43	US 183 frontage road inlet
2	0.06	0.11	US 183 frontage road
Peak Flow (cfs)			
A	43.66	45.04	Pipe d/s of improvements
B	-77.61	14.69	Walnut Creek Trib. 7



LAN PROJECT #: 120-11884-001

STRUCTURES

FLOODING REMOVED

- 100-YR
- 25-YR
- 10-YR
- 2-YR

FLOODING REDUCED

- W.S. ELEV DECREASED
- DIFFERENT FROM PER

PONDING/FLOODING

EXISTING

- ≥ 0.3'

PROPOSED

- 0.3' - 0.5'
- > 0.5' - 1'
- > 1' - 2'
- > 2'

Flooding is based on a calculated average Finished Floor Elevation of 0.8 ft from survey data

0 50 100

Feet

OAK KNOLL AREA
30% DESIGN W/ POND 100-YR INUNDATION

LEGEND

- 2 FT CONTOURS
- LOT LINES
- AREA OF INFLUENCE
- EXISTING INLETS
- PROPOSED INLETS
- EXISTING STORM DRAIN
- PROPOSED STORM DRAIN

REPORTED FLOODING

- BUILDING
- STREET
- YARD

100-YR BENEFITS

- REMOVED
- HELEPD
- NOT HELPED

EXHIBIT 1

Lockwood, Andrews & Newnam, Inc.
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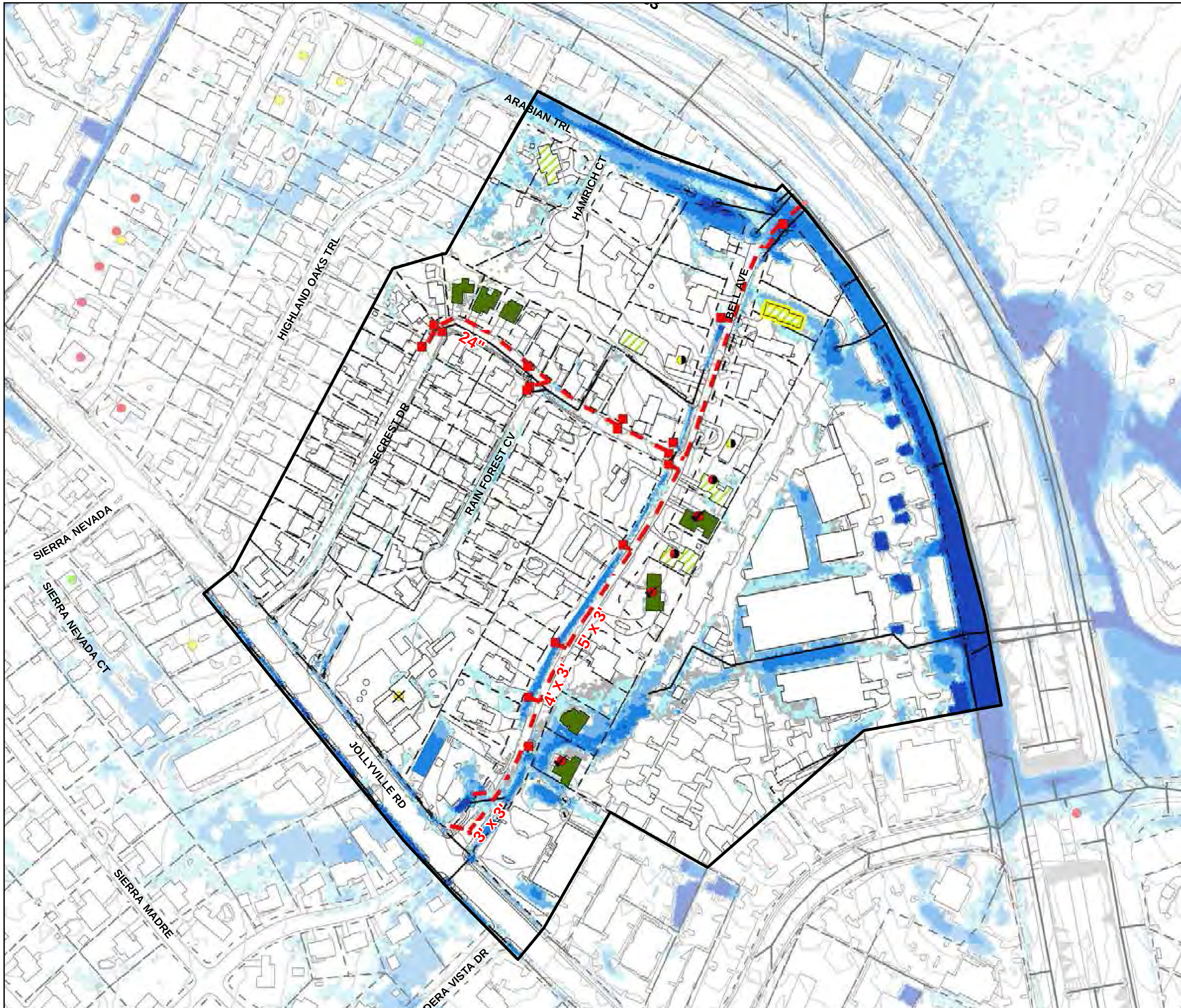
Lockwood, Andrews & Newnam Inc. makes no representations or warranties regarding accuracy or completeness of the information depicted on this map or the data from which it was produced. This map is NOT suitable for survey purposes and does not purport to depict or establish boundaries between land owners or locations of utility infrastructure where survey data is available and field locations have been established.



LAN PROJECT #: 120-11884-001

STRUCTURES

FLOODING REMOVED

- 100-YR
- 25-YR
- 10-YR
- 2-YR

FLOODING REDUCED

- W.S. ELEV DECREASED
- DIFFERENT FROM PER

PONDING/FLOODING

EXISTING

- ≥ 0.3'

PROPOSED

- 0.3' - 0.5'
- > 0.5' - 1'
- > 1' - 2'
- > 2'

Flooding is based on a calculated average Finished Floor Elevation of 0.8 ft from survey data

0 125 250
Feet

BELL AVENUE AREA
30% DESIGN
100-YR INUNDATION

LEGEND

- 2 FT CONTOURS
- LOT LINES
- AREA OF INFLUENCE
- EXISTING INLETS
- PROPOSED INLETS
- EXISTING STORM DRAIN
- PROPOSED STORM DRAIN

REPORTED FLOODING

- BUILDING
- STREET
- YARD

100-YR BENEFITS

- REMOVED
- HELPED
- NOT HELPED

EXHIBIT 2

Lockwood, Andrews & Newnam, Inc.
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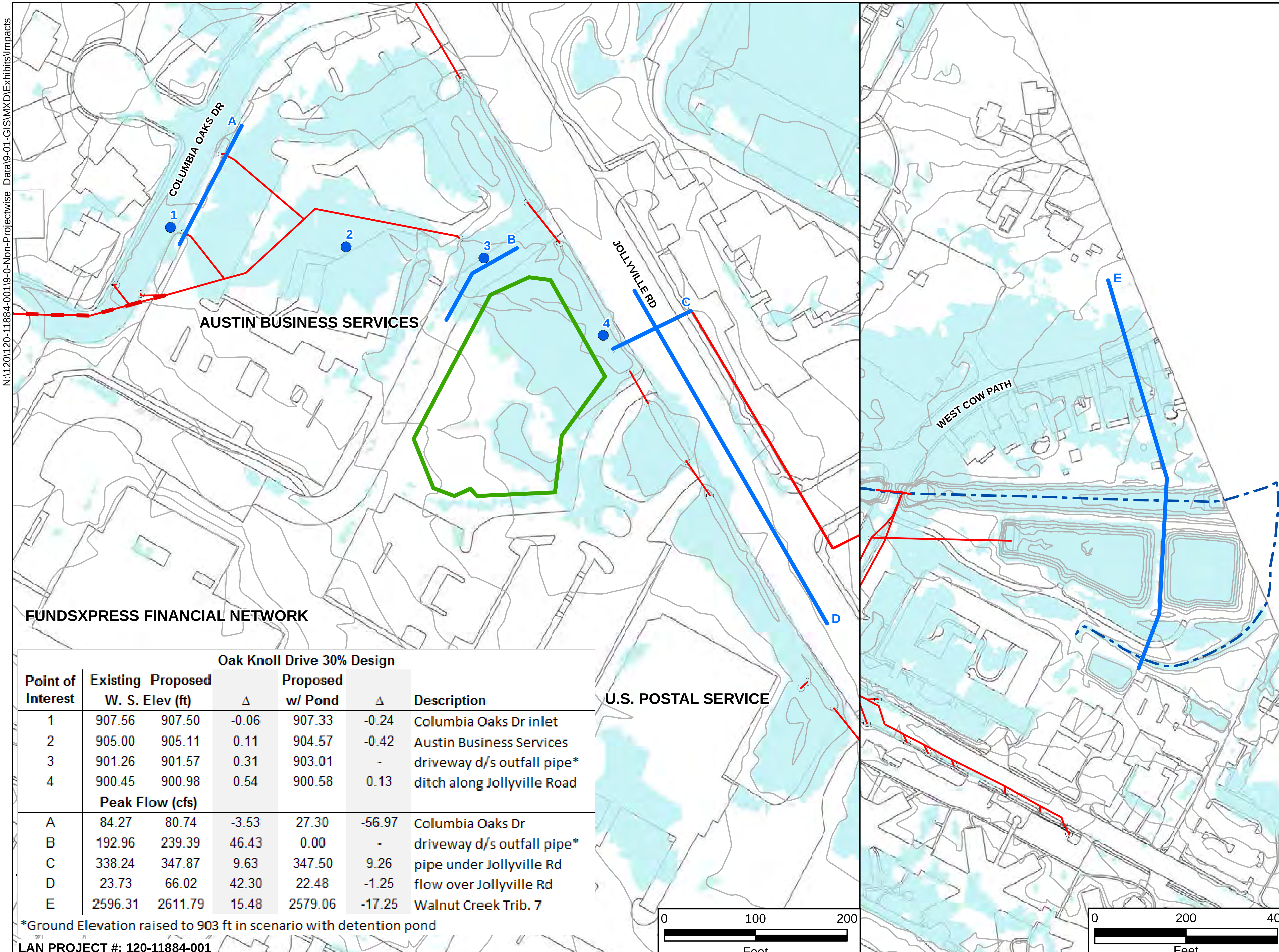
N:\120\120-11884-001\9-0-Non-Projectwise Data\9-01-GIS\MXD\Exhibits\Impacts

OAK KNOLL AREA
ALTERNATIVE 3 WITH DETENTION 100-YR IMPACTS



Point of Interest	Existing W. S. Elev (ft)	Proposed (Oak Knoll Drive 30% Design)	Δ	Proposed w/ Pond	Δ	Description
1	907.56	907.50	-0.06	907.33	-0.24	Columbia Oaks Dr inlet
2	905.00	905.11	0.11	904.57	-0.42	Austin Business Services
3	901.26	901.57	0.31	903.01	-	driveway d/s outfall pipe*
4	900.45	900.98	0.54	900.58	0.13	ditch along Jollyville Road
	Peak Flow (cfs)					
A	84.27	80.74	-3.53	27.30	-56.97	Columbia Oaks Dr
B	192.96	239.39	46.43	0.00	-	driveway d/s outfall pipe*
C	338.24	347.87	9.63	347.50	9.26	pipe under Jollyville Rd
D	23.73	66.02	42.30	22.48	-1.25	flow over Jollyville Rd
E	2596.31	2611.79	15.48	2579.06	-17.25	Walnut Creek Trib. 7

*Ground Elevation raised to 903 ft in scenario with detention pond

LAN PROJECT #: 120-11884-001

LEGEND

- EXISTING INUNDATION
- 2 FT CONTOURS
- WALNUT CREEK TRIBUTARY 7
- PROPOSED STORM DRAIN
- EXISTING STORM DRAIN PIPES
- EXISTING INLETS
- RESULTS LINE (POI)
- POINTS OF INTEREST
- DETENTION POND

EXHIBIT 3

Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY

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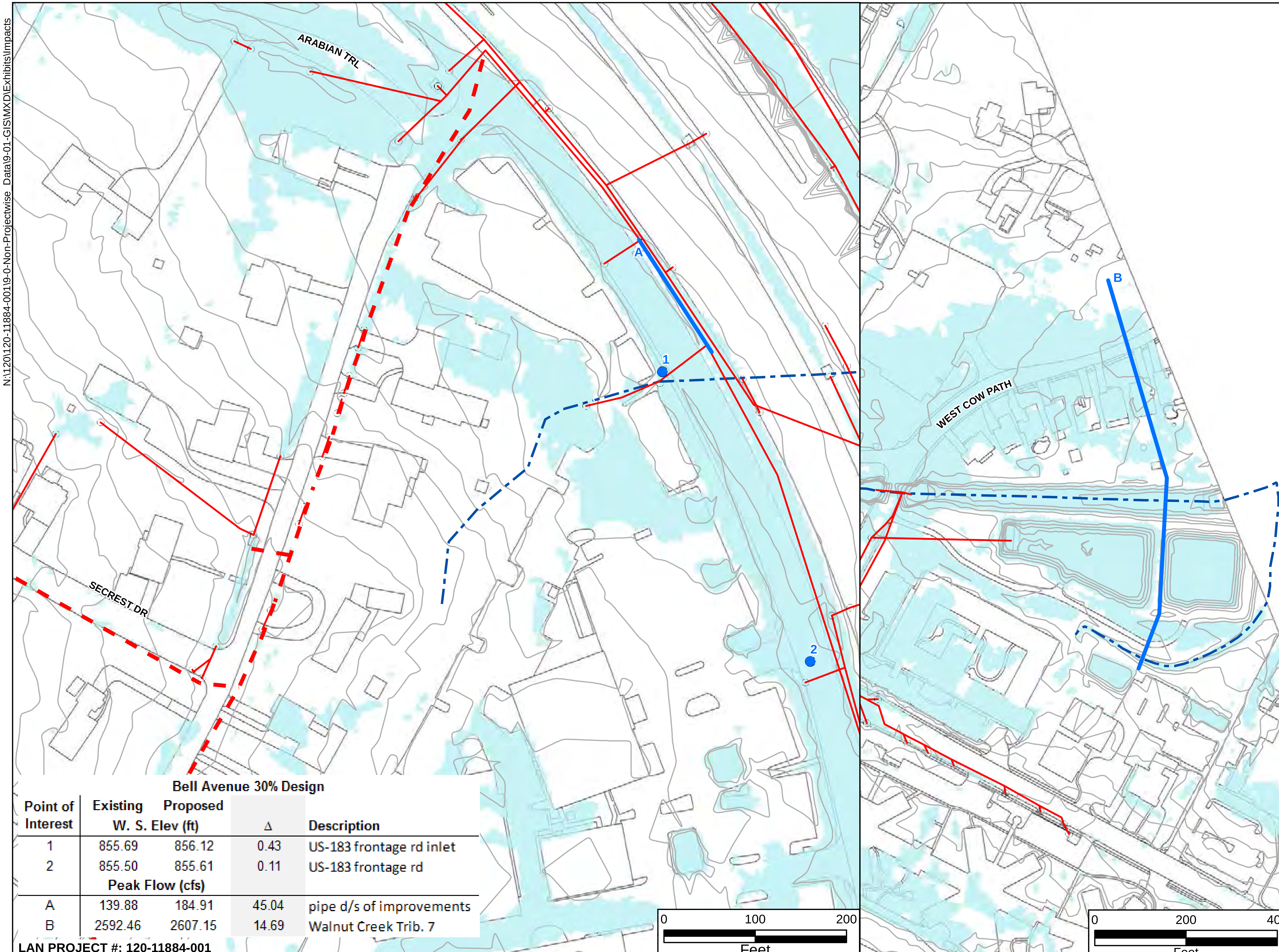

Point of Interest	Existing W. S. Elev (ft)	Proposed W. S. Elev (ft)	Δ	Description
1	855.69	856.12	0.43	US-183 frontage rd inlet
2	855.50	855.61	0.11	US-183 frontage rd
	Peak Flow (cfs)			
A	139.88	184.91	45.04	pipe d/s of improvements
B	2592.46	2607.15	14.69	Walnut Creek Trib. 7

Bell Avenue 30% Design

LAN PROJECT #: 120-11884-001

CITY OF AUSTIN FOUNDED 1839

BELL AVENUE AREA
30% DESIGN
100-YR IMPACTS

LEGEND

- EXISTING INUNDATION
- 2 FT CONTOURS
- WALNUT CREEK TRIBUTARY 7
- EXISTING STORM DRAIN PIPES
- EXISTING INLETS
- RESULTS LINE (POI)
- POINTS OF INTEREST

N

EXHIBIT 4

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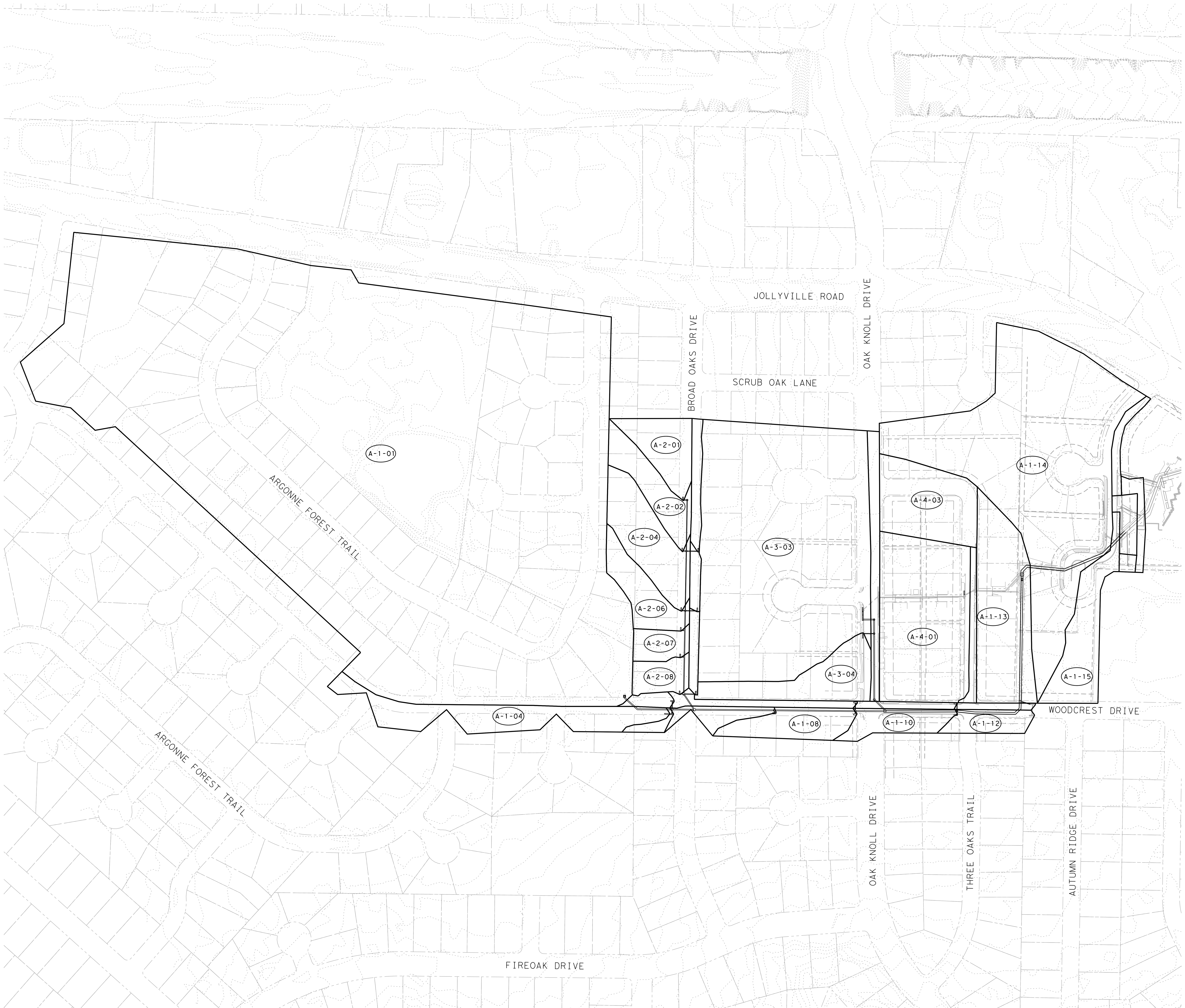

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LEGEND

- EXISTING E.O.P.
- EXISTING R.O.W.
- PROPOSED E.O.P.
- DRAINAGE AREA
- EXISTING 2-FT CONTOUR
- DITCH CENTERLINE
- FLOW DIRECTION
- X.XX DRAINAGE AREA ID

0 75 150
HORIZONTAL SCALE IN FEET

REV NO.	BY	DATE	REVISION DESCRIPTION

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL OFFSITE DRAINAGE AREA MAP

CITY OF AUSTIN FOUNDED 1839

NOTES	NAME	DATE
SURVEY BY		
DRAWN BY	MB	
CHECKED BY	DC	
DESIGNED BY	TJK	
REVIEWED BY		

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1 OF 30

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LEGEND

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EXISTING R.O.W.
PROPOSED E.O.P.
DRAINAGE AREA
EXISTING 1-FT CONTOUR
DITCH CENTERLINE
FLOW DIRECTION
X.XX DRAINAGE AREA ID
X.XX DRAINAGE NODE

0 30 60
HORIZONTAL SCALE IN FEET

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRAINAGE AREA MAP
1 OF 7

CITY OF AUSTIN FOUNDED 1839

NOTES	NAME	DATE
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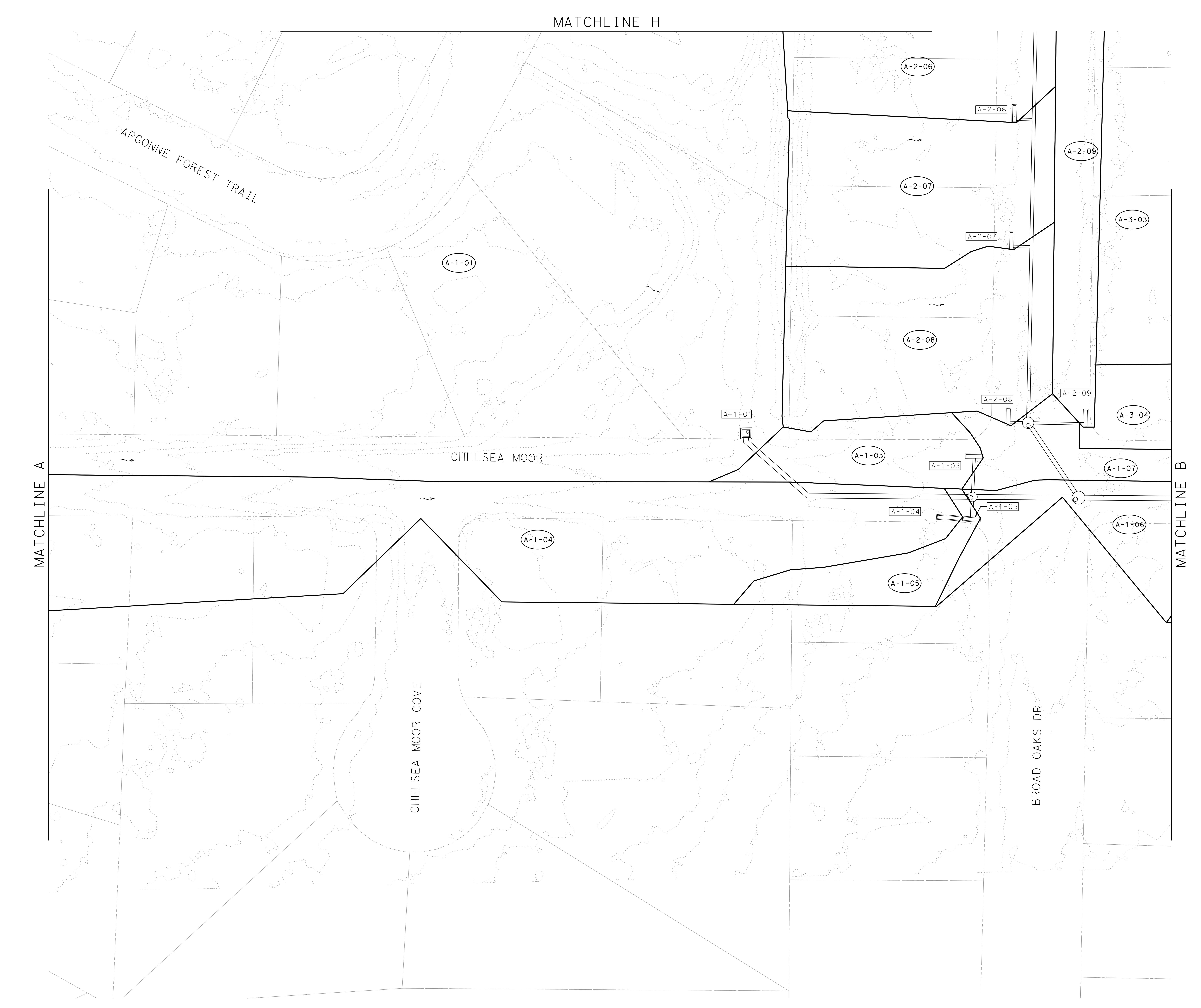

LEGEND

EXISTING E.O.P.
EXISTING R.O.W.
PROPOSED E.O.P.
DRAINAGE AREA
EXISTING 1-FT CONTOUR
DITCH CENTERLINE
FLOW DIRECTION
X.XX DRAINAGE AREA ID
X.XX DRAINAGE NODE

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRAINAGE AREA MAP
2 OF 7

CITY OF AUSTIN FOUNDED 1839

NOTES	NAME	DATE
SURVEY BY		
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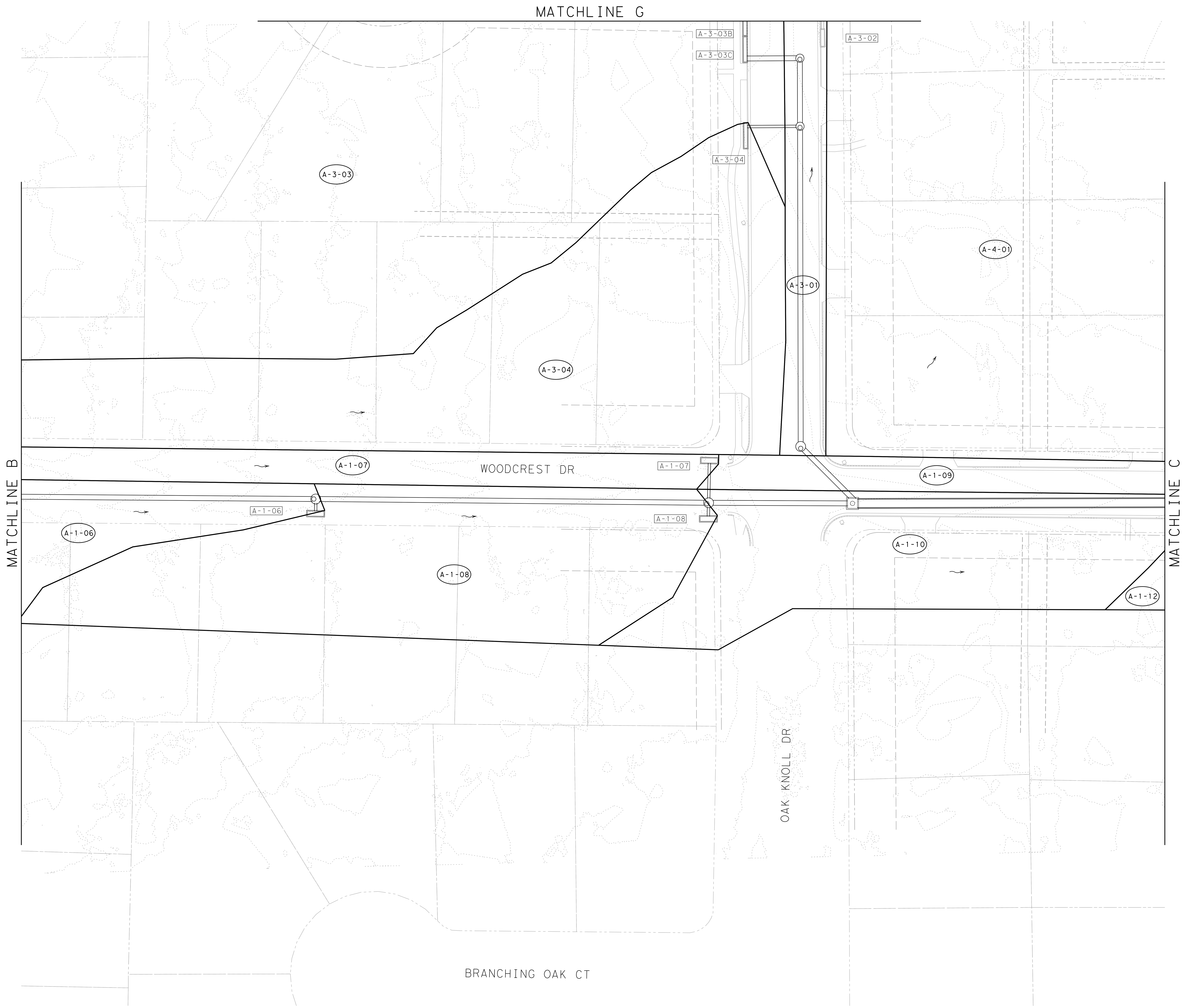

LEGEND

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EXISTING E.O.P.
EXISTING R.O.W.
PROPOSED E.O.P.
DRAINAGE AREA
EXISTING 1-FT CONTOUR
DITCH CENTERLINE
FLOW DIRECTION
X.XX DRAINAGE AREA ID
X.XX DRAINAGE NODE

0 30 60
HORIZONTAL SCALE IN FEET

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRAINAGE AREA MAP 3 OF 7

NOTES	NAME	DATE
SURVEY BY		
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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRAINAGE AREA MAP 4 OF 7

CITY OF AUSTIN FOUNDED 1839

NOTES	NAME	DATE
SURVEY BY		
DRAWN BY	MB	
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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRAINAGE AREA MAP 5 OF 7

CITY OF AUSTIN FOUNDED 1839

NOTES	NAME	DATE
SURVEY BY		
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LEGEND

EXISTING E.O.P.
EXISTING R.O.W.
PROPOSED E.O.P.
DRAINAGE AREA
EXISTING 1-FT CONTOUR
DITCH CENTERLINE
FLOW DIRECTION
X.XX DRAINAGE AREA ID
X.XX DRAINAGE NODE

REV NO.	BY	DATE	REVISION DESCRIPTION

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRAINAGE AREA MAP
6 OF 7

NOTES	NAME	DATE
SURVEY BY		
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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRAINAGE AREA MAP 7 OF 7

NOTES	NAME	DATE
SURVEY BY		
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DRAINAGE AREA CALCULATIONS

AREA ID	AREA (AC)	TC CALCULATED (MIN)	TC USED (MIN)	C_{25}	I_{25} (IN/HR)	Q_{25} (CFS)	C_{100}	I_{100} (IN/HR)	Q_{100} (CFS)	NOTES
A-1-01	36.46	20.0	20.0	0.16	6.27	35.9	0.15	8.13	44.8	5
A-1-03	0.12	3.1	5.0	0.69	10.10	0.9	0.77	12.50	1.2	
A-1-04	1.41	16.6	16.6	0.65	6.79	6.3	0.73	8.83	9.2	
A-1-05	0.09	11.5	11.5	0.58	8.11	0.4	0.66	10.33	0.6	
A-1-06	0.29	2.5	5.0	0.68	10.10	2.0	0.76	12.50	2.8	
A-1-07	0.29	8.5	8.5	0.77	9.03	2.0	0.85	11.33	2.8	
A-1-08	0.67	15.8	15.8	0.61	6.92	2.9	0.69	9.00	4.2	
A-1-09	0.14	2.3	5.0	0.79	10.10	1.1	0.88	12.50	1.5	
A-1-10	0.50	15.0	15.0	0.66	7.04	2.4	0.74	9.16	3.4	
A-1-11	0.10	1.9	5.0	0.80	10.10	0.9	0.89	12.50	1.2	
A-1-12	0.38	9.9	9.9	0.67	8.60	2.2	0.76	10.86	3.2	
A-1-13	2.03	14.0	14.0	0.56	7.35	8.5	0.64	9.49	12.4	
A-1-14	7.21	16.7	16.7	0.61	6.78	30.0	0.69	8.81	44.2	
A-1-15	1.08	17.2	17.2	0.67	6.70	4.9	0.75	8.71	7.1	
A-1-16	0.23	1.4	5.0	0.80	10.10	1.9	0.89	12.50	2.6	
A-1-17	0.19	1.3	5.0	0.82	10.10	1.6	0.91	12.50	2.2	
A-1-18	0.18	2.9	5.0	0.72	10.10	1.3	0.80	12.50	1.8	
A-1-19	0.06	0.3	5.0	0.78	10.10	0.5	0.86	12.50	0.6	
A-2-01	0.71	18.9	18.9	0.59	6.44	2.7	0.66	8.36	4.0	
A-2-02	0.72	19.1	19.1	0.62	6.41	2.9	0.70	8.32	4.2	
A-2-03	0.38	2.8	5.0	0.78	10.10	3.0	0.87	12.50	4.2	
A-2-04	1.14	19.6	19.6	0.64	6.33	4.7	0.72	8.22	6.8	
A-2-05	0.13	1.5	5.0	0.78	10.10	1.0	0.87	12.50	1.4	
A-2-06	0.68	13.0	13.0	0.62	7.65	3.3	0.70	9.83	4.7	
A-2-07	0.33	10.7	10.7	0.56	8.36	1.6	0.64	10.60	2.3	
A-2-08	0.37	13.0	13.0	0.60	7.65	1.7	0.67	9.83	2.5	
A-2-09	0.15	4.1	5.0	0.77	10.10	1.2	0.86	12.50	1.7	
A-3-01	0.51	3.4	5.0	0.85	10.10	4.4	0.93	12.50	6.0	
A-3-03	8.14	19.5	19.5	0.60	6.34	31.2	0.68	8.24	46.0	
A-3-04	1.06	16.8	16.8	0.61	6.76	4.4	0.68	8.79	6.4	
A-4-01	2.88	18.5	18.5	0.60	6.50	11.3	0.68	8.44	16.7	
A-4-02	0.23	2.5	5.0	0.77	10.10	1.8	0.86	12.50	2.4	
A-4-03	1.39	12.1	12.1	0.66	7.93	7.3	0.74	10.13	10.5	

NOTES:

INLET AND STORM DRAIN CALCULATIONS WERE COMPLETED USING BENTLEY STORMCAD V8I.

1. EXISTING STRUCTURE
2. INLET CALCULATION REPRESENTS MULTIPLE INLET STRUCTURES ACTING TOGETHER HYDRAULICALLY AT A LOW POINT.
3. BYPASS FLOW LEAVES THE SYSTEM.
4. TAILWATER SET TO SOFFIT OF PIPE.
5. PEAK FLOW FOR DRAINAGE AREA WAS CALIBRATED TO INFOWORKS ICM RESULTS DUE TO UPSTREAM DETENTION AND FLOW DIVERSION. TIME OF CONCENTRATION WAS TAKEN FROM TIME TO PEAK IN ICM MODEL. C VALUE WAS CALIBRATED TO MATCH PEAK FLOW FROM ICM.

CURB INLET CALCULATIONS (25-YR)

INLET ID	TYPE	DRAINAGE AREA ID	DRAINAGE AREA FLOW (CFS)	CARRY-OVER FLOW Q_{PASS} (CFS)	TOTAL RUN-OFF Q_A (CFS)	PROFILE TYPE	PROFILE SLOPE S_L (%)	GUTTER DEPRESSION A (FT)	PONDED DEPTH Y_0 (FT)	ALLOWABLE PONDED WIDTH (FT)	PONDED WIDTH T (FT)	CLOG REDUCTION FACTOR	Q_A/L_A	L_A (FT)	INLET LENGTH L (FT)	L/L_A	A/Y_0	Q/Q_A	Q (CFS)	BYPASS FLOW Q_{PASS} (CFS)	BYPASS INLET ID	NOTES
A-1-01	AI 508S-9	A-1-01	35.93	0.00	35.93	In Sag	N/A	0.17	1.05	12.0	4.2	N/A	N/A	N/A	16	N/A	0.16	1.00	35.93	N/A	N/A	
A-1-03	CI 508S-3	A-1-03	0.86	0.00	0.86	On Grade	0.019	0.48	0.14	13.0	4.7	N/A	0	4.9	10	2.05	3.39	1.00	0.86	0.00	A-1-07	
A-1-04	CI 508S-3	A-1-04	6.33	0.00	6.33	On Grade	0.019	0.48	0.26	17.0	12.8	N/A	0	17.4	15	0.86	1.83	0.97	6.11	0.22	A-1-05	
A-1-05	CI 508S-3	A-1-05	0.41	0.22	0.64	On Grade	0.019	0.48	0.11	17.0	5.4	N/A	0	4.4	10	2.28	4.32	1.00	0.64	0.00	A-1-06	
A-1-06	CI 508S-3	A-1-06	1.98	0.00	1.98	On Grade	0.015	0.48	0.17	13.0	8.6	N/A	0	8.6	10	1.17	2.79	1.00	1.98	0.00	A-1-08	
A-1-07	CI 508S-3	A-1-07	2.01	0.00	2.01	On Grade	0.014	0.48	0.18	13.0	8.8	N/A	0	8.3	10	1.20	2.64	1.00	2.01	0.00	A-1-09	
A-1-08	CI 508S-3	A-1-08	2.85	0.00	2.85	On Grade	0.014	0.48	0.20	13.0	10.0	N/A	0	10.3	10	0.97	2.38	1.00	2.84	0.01	A-1-10	
A-1-09	CI 508S-3	A-1-09	1.12	0.00	1.12	On Grade	0.020	0.48	0.17	13.0	4.3	N/A	0	5.2	10	1.91	2.79	1.00	1.12	0.00	A-1-11	
A-1-10	CI 508S-3	A-1-10	2.35	0.01	2.36	On Grade	0.020	0.48	0.23	13.0	5.7	N/A	0	7.9	10	1.27	2.07	1.00	2.36	0.00	A-1-12	
A-1-11	CI 508S-3	A-1-11	0.85	0.00	0.85	On Grade	0.018	0.48	0.12	13.0	6.1	N/A	0	5.2	15	2.90	3.96	1.00	0.85	0.00		1, 3
A-1-12	CI 508S-3	A-1-12	2.22	0.00	2.22	On Grade	0.018	0.48	0.17	13.0	8.7	N/A	0	8.9	15	1.69	2.79	1.00	2.22	0.00		1, 3
A-1-13	AI 508S-9	A-1-13	8.46	0.00	8.46	In Sag	N/A	0.17	0.31	10.0	10.5	N/A	N/A	N/A	16	N/A	0.54	1.00	8.46	N/A	N/A	
A-2-01	CI 508S-3	A-2-01	2.70	0.00	2.70	On Grade	0.018	0.48	0.19	10.0	9.4	N/A	0	10.5	10	0.95	2.50	0.99	2.68	0.02	A-2-02	
A-2-02	CI 508S-3	A-2-02	2.90	0.02	2.92	On Grade	0.027	0.48	0.18	10.0	8.9	N/A	0	11.9	10	0.84	2.64	0.95	2.78	0.14	A-2-04	
A-2-03	CI 508S-3	A-2-03	3.04	0.00	3.04	On Grade	0.027	0.48	0.18	10.0	9.1	N/A	0	12.5	10	0.80	2.64	0.94	2.87	0.17	A-2-05	
A-2-04	CI 508S-3	A-2-04	4.65	0.14	4.79	On Grade	0.007	0.48	0.32	10.0	10.8	N/A	0	10.1	10	0.99	1.48	1.00	4.77	0.01	A-2-06	
A-2-05	CI 508S-3	A-2-05	1.03	0.17	1.20	On Grade	0.007	0.48	0.16	10.0	8.3	N/A	0	5.4	10	1.86	2.97	1.00	1.20	0.00	A-2-09	
A-2-06	CI 508S-3	A-2-06	3.28	0.01	3.30	On Grade	0.004	0.48	0.27	10.0	13.4	N/A	0	8.5	10	1.18	1.76	1.00	3.30	0.00	A-2-07	
A-2-07	CI 508S-3	A-2-07	1.56	0.00	1.56	On Grade	0.004	0.48	0.20	10.0	10.1	N/A	0	5.4	10	1.84	2.38	1.00	1.56	0.00	A-2-08	
A-2-08	CI 508S-3	A-2-08	1.69	0.00	1.69	On Grade	0.005	0.48	0.20	10.0	10.0	N/A	0	6.0	10	1.66	2.38	1.00	1.69	0.00	A-1-06	
A-2-09	CI 508S-3	A-2-09	1.20	0.00	1.20	On Grade	0.005	0.48	0.18	10.0	8.8	N/A	0	5.0	10	1.99	2.64	1.00	1.20	0.00	A-1-07	
A-3-01	CI 508S-3	A-3-01	4.40	0.00	4.40	In Sag	N/A	0.48	0.13	10.0	2.2	N/A	N/A	N/A	30	N/A	3.65	1.00	4.40	N/A	N/A	1, 2
A-3-03	CI 508S-3	A-3-03	31.23	0.00	31.24	In Sag	N/A	0.48	0.45	10.0	9.9	N/A	N/A	N/A	35	N/A	1.06	1.00	31.24	N/A	N/A	2
A-3-04	CI 508S-3	A-3-04	4.39	0.00	4.39	On Grade	0.025	0.48	0.21	10.0	10.6	N/A	0	15.0	15	1.00	2.26	1.00	4.39	0.00	A-3-03	
A-4-01	CI 508S-3	A-4-01	11.31	0.00	11.31	In Sag	N/A	0.48	0.33	13.0	8.2	N/A	N/A	N/A	20	N/A	1.44	1.00	11.31	N/A	N/A	1, 2
A-4-02	CI 508S-3	A-4-02	1.77	1.30	3.07	In Sag	N/A	0.48	0.14	13.0	2.0	N/A	N/A	N/A	20	N/A	3.39	1.00	3.07	N/A	N/A	1
A-4-03	CI 508S-3	A-4-03	7.32	0.00	7.32	On Grade	0.017	0.48	0.32	13.0	10.7	N/A	0	16.2	10	0.62	1.48	0.82	6.02	1.30	A-4-02	1

REV. NO.	BY	DATE	REVISION DESCRIPTION

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL
STORM DRAIN HYDRAULIC DATA

CITY OF AUSTIN FOUNDED 1839

NOTES	NAME	DATE
SURVEY BY		
DRAWN BY	MB	
CHECKED BY	DC	
DESIGNED BY	TJK	
REVIEWED BY		

Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY
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TBPE Firm #6535

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STORM DRAIN HYDRAULIC CALCULATIONS (25-YR)

LINK ID	MANHOLES/INLETS FROM	MANHOLES/INLETS TO	DIST. FEET	DISCHARGE C.F.S.	PIPE SIZE	FRICTION GRADE FT/FT	HYDR. GRADIENT UP STREAM ELEV.	HYDR. GRADIENT DOWN STREAM ELEV.	V_1 INFLOW F.P.S.	V_2 OUTFLOW F.P.S.	V_2^2 / 2g FT.	V_1^2 / 2g FT.	K_j CONST	$K_jV_1^2$ / 2g FT.	h FT.	H.G.EL. DESIGN PT. ELEV.	INV. IN FEET	INV. OUT FT/FT	NOTES
A-1-01	A-1-01	A-1.01	2.84	35.93	36" RCP	0.0040	931.60	931.59	N/A	6.79	0.72	N/A	1.25	0.89	0.90	932.50	929.50	929.49	
A-1.01	A-1.01	A-1.02	50.51	35.92	36" RCP	0.0050	931.44	931.32	6.79	8.04	1.00	0.72	0.18	0.13	0.15	931.59	929.49	929.22	
A-1.02	A-1.02	A-1.03	98.63	35.83	36" RCP	0.0050	931.17	930.73	8.04	7.99	0.99	1.00	0.18	0.18	0.15	931.32	929.22	928.70	
A-1.03	A-1.03	A-1.04	59.16	42.26	36" RCP	0.0090	930.72	929.30	7.99	12.44	2.40	0.99	0.07	0.07	0.06	930.78	928.60	927.70	
A-1.04	A-1.04	A-1.05	228.49	60.51	36" RCP	0.0140	929.11	925.87	12.44	13.28	2.74	2.40	0.07	0.18	0.10	929.22	926.60	923.30	
A-1.05	A-1.05	A-1.06	231.88	61.28	36" RCP	0.0110	925.72	923.20	13.28	12.03	2.25	2.74	0.10	0.28	0.15	925.87	923.20	920.60	
A-1.06	A-1.06	A-1.07	81.26	64.65	36" RCP	0.0100	923.08	921.50	12.03	13.12	2.67	2.25	0.08	0.18	0.12	923.20	920.50	919.40	
A-1.07	A-1.07	A-1.08	205.95	98.41	5' x 3' CBC	0.0050	916.59	915.77	13.12	9.41	1.37	2.67	0.07	0.18	0.08	916.67	914.30	913.30	
A-1.08	A-1.08	A-1.09	50.77	100.18	5' x 3' CBC	0.0050	915.62	915.33	9.41	9.50	1.40	1.37	0.13	0.18	0.15	915.77	913.30	913.05	
A-1.09	A-1.09	A-1.10	117.94	99.95	5' x 3' CBC	0.0050	915.37	914.98	9.50	9.55	1.42	1.40	0.01	0.01	0.01	915.38	913.05	912.46	
A-1.10	A-1.10	A-1.11	19.96	99.42	5' x 3' CBC	0.0040	914.77	914.87	9.55	9.54	1.41	1.42	0.18	0.25	0.21	914.98	912.46	912.36	
A-1.11	A-1.11	A-1.12	17.71	99.33	5' x 3' CBC	0.0040	914.67	914.43	9.54	9.59	1.43	1.41	0.18	0.25	0.21	914.87	912.36	912.27	
A-1.12	A-1.12	A-1-13	352.45	101.30	5' x 3' CBC	0.0140	913.34	908.53	9.59	13.94	3.02	1.43	0.07	0.10	0.08	913.42	911.00	906.00	
A-1-13	A-1-13	A-1.13	8.92	115.18	5' x 3' CBC	0.0050	908.45	908.06	9.59	13.31	2.75	1.43	0.07	0.10	0.09	908.53	905.90	905.80	
A-1.13	A-1.13	A-1.14	6.08	134.29	6' x 3' CBC	0.0120	908.20	908.32	13.94	15.58	3.77	3.02	0.06	0.19	0.08	908.27	905.70	905.60	
A-1.14	A-1.14	A-1.15	20.00	134.27	6' x 3' CBC	0.0140	908.10	908.03	15.58	15.09	3.54	3.77	0.18	0.68	0.22	908.32	905.60	905.30	
A-1.15	A-1.15	A-1.16	111.01	134.20	6' x 3' CBC	0.0150	907.80	906.22	15.09	15.19	3.58	3.54	0.19	0.67	0.24	908.03	905.30	903.60	
A-1.16	A-1.16	A-1.17	121.66	133.79	6' x 3' CBC	0.0080	906.09	905.18	15.19	12.21	2.31	3.58	0.10	0.36	0.12	906.22	903.60	902.60	
A-1.17	A-1.17	A-1.18	51.09	133.25	6' x 3' CBC	0.0080	905.08	905.08	12.21	14.73	3.37	2.31	0.08	0.19	0.10	905.18	902.60	901.88	
A-1.18	A-1.18	A-1.19	33.14	158.92	6' x 3' CBC	0.0050	905.00	904.83	14.73	8.83	1.21	3.37	0.07	0.50	0.08	905.08	901.88	901.78	
A-1.19	A-1.19	A-1.20	8.25	162.91	6' x 3' CBC	0.0030	904.74	904.60	8.83	9.05	1.27	1.21	0.07	0.50	0.09	904.83	901.78	901.76	
A-1.20	A-1.20	A-1.21	7.46	162.85	6' x 3' CBC	0.0070	904.60	904.64	9.05	12.82	2.55	1.27	0.00	0.00	0.00	904.60	901.76	901.70	1
A-1.21	A-1.21	A-1.22	59.05	163.08	6' x 3' CBC	0.0090	904.54	904.16	12.82	16.46	4.21	2.55	0.07	0.50	0.10	904.64	901.70	900.74	1
A-1.22	A-1.22	A-1-17	8.97	163.91	6' x 3' CBC	0.0050	904.07	904.02	16.46	9.11	1.29	4.21	0.07	0.50	0.10	904.16	900.74	900.62	1
A-1.22.1	A-1-17	A-1.23	15.52	166.33	6' x 3' CBC	0.0060	903.93	903.85	9.11	9.24	1.33	1.29	0.06	0.50	0.08	904.02	900.62	900.50	1
A-1.23	A-1.23	A-1.24	86.76	166.21	6' x 3' CBC	0.0060	903.71	903.23	9.24	9.23	1.32	1.33	0.10	0.13	0.13	903.85	900.50	899.91	1
A-1.24	A-1.24	A-1.25	16.61	166.31	6' x 3' CBC	0.0060	903.13	903.04	9.23	9.24	1.33	1.32	0.07	0.50	0.10	903.23	899.91	899.79	1
A-1.25	A-1.25	A-1.26	158.90	166.19	6' x 3' CBC	0.0060	902.67	901.79	9.24	12.14	2.29	1.33	0.26	0.34	0.37	903.04	899.79	898.71	1
A-1.26	A-1.26	A-1-OUT	3.11	165.28	6' x 3' CBC	0.0060	901.58	901.68	12.14	13.75	2.94	2.29	0.15	0.34	0.22	901.79	898.71	898.68	1, 4
A-2.1	A-2.1	A-2.2	145.55	2.68	18" RCP	0.0300	938.12	933.99	13.75	7.95	0.98	2.94	0.49	1.44	0.11	938.24	937.50	932.90	
A-2.2	A-2.2	A-2.3	170.79	7.25	18" RCP	0.0090	933.84	932.14	7.95	6.25	0.61	0.98	0.23	0.22	0.11	933.95	932.80	931.20	
A-2.3	A-2.3	A-2.4	55.78	12.68	24" RCP	0.0070	931.18	930.98	6.25	7.19	0.80	0.61	0.13	0.08	0.07	931.25	929.90	929.46	
A-2.4	A-2.4	A-2.5	78.08	15.35	24" RCP	0.0050	930.87	930.70	7.19	7.53	0.88	0.80	0.17	0.14	0.11	930.98	929.46	928.84	
A-2.5	A-2.5	A-2.6	105.15	16.46	24" RCP	0.0050	930.62	930.14	7.53	7.17	0.80	0.88	0.14	0.12	0.07	930.69	928.84	928.00	
A-2.6	A-2.6	A-1.04	48.93	18.48	30" RCP	0.0020	930.02	929.93	7.17	3.76	0.22	0.80	0.53	0.42	0.12	930.14	927.40	927.20	
A-3.1	A-3.1	A-3.2	37.08	31.18	36" RCP	0.0020	917.88	917.87	3.76	7.81	0.95	0.22	0.66	0.14	0.30	918.18	915.60	915.40	
A-3.2	A-3.2	A-3.3	188.61	35.22	36" RCP	0.0020	917.83	917.49	7.81	6.49	0.65	0.95	0.10	0.09	0.05	917.87	915.30	914.70	
A-3.3	A-3.3	A-1.07	41.79	34.80	36" RCP	0.0020	917.26	917.21	6.49	7.64	0.91	0.65	0.53	0.34	0.23	917.49	914.60	914.40	
A-3-01	A-3-01	A-4-01	248.22	4.40	24" RCP	0.0190	918.03	913.55	7.64	7.61	0.90	0.91	1.00	0.91	0.00	918.03	917.29	912.24	1
A-4-01	A-4-01	A-4-02	35.32	14.14	27" RCP	0.0050	913.55	913.57	7.61	6.48	0.65	0.90	1.00	0.90	0.00	913.55	912.24	912.01	1
A-4-02	A-4-02	A-4-02.1	86.43	21.00	30" RCP	0.0180	913.57	910.49	6.48	12.44	2.40	0.65	1.00	0.65	0.00	913.57	912.01	909.51	1
A-4-02.1	A-4-02.1	A-1.13	66.39	20.94	30" RCP	0.0150	911.07	908.51	12.44	13.29	2.74	2.40	1.00	2.40	0.00	911.07	909.51	907.54	1

NOTES:

INLET AND STORM DRAIN CALCULATIONS WERE COMPLETED USING BENTLEY STORMCAD V8I.

1. EXISTING STRUCTURE
2. INLET CALCULATION REPRESENTS MULTIPLE INLET STRUCTURES ACTING TOGETHER HYDRAULICALLY AT A LOW POINT.
3. BYPASS FLOW LEAVES THE SYSTEM.
4. TAILWATER SET TO SOFFIT OF PIPE.

REV. NO.	BY	DATE	REVISION DESCRIPTION

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL
STORM DRAIN HYDRAULIC DATA

NOTES	NAME	DATE
SURVEY BY		
DRAWN BY	MB	
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Austin, Texas 78746
TBPE Firm #6535

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STORM DRAIN HYDRAULIC CALCULATIONS (100-YR)

LINK ID	MANHOLES/INLETS FROM	MANHOLES/INLETS TO	DIST.	DISCHARGE	PIPE SIZE	FRICTION GRADE	HYDR. GRADIENT UP STREAM	HYDR. GRADIENT DOWN STREAM	V_1 INFLOW	V_2 OUTFLOW	V_2^2 / 2g	V_1^2 / 2g	K_j	$K_jV_1^2$ / 2g	h	H.G.EL. DESIGN PT.	INV. IN	INV. OUT	NOTES
			FEET	C.F.S.		FT/FT	ELEV.	ELEV.	F.P.S.	F.P.S.	FT.	FT.	CONST	FT.	FT.	ELEV.	FEET	FT/FT	
A-1-01	A-1-01	A-1.01	2.84	44.83	36" RCP	0.0040	931.87	931.86	N/A	6.88	0.74	N/A	1.25	0.92	1.09	932.96	929.50	929.49	
A-1.01	A-1.01	A-1.02	50.51	44.83	36" RCP	0.0050	931.67	931.58	6.88	8.39	1.09	0.74	0.18	0.13	0.19	931.86	929.49	929.22	
A-1.02	A-1.02	A-1.03	98.63	44.71	36" RCP	0.0050	931.40	931.08	8.39	8.33	1.08	1.09	0.18	0.20	0.18	931.58	929.22	928.70	
A-1.03	A-1.03	A-1.04	59.16	53.97	36" RCP	0.0090	930.99	929.57	8.33	13.21	2.71	1.08	0.07	0.08	0.09	931.08	928.60	927.70	
A-1.04	A-1.04	A-1.05	228.49	80.48	36" RCP	0.0130	929.37	926.64	13.21	13.95	3.02	2.71	0.08	0.21	0.17	929.54	926.60	923.30	
A-1.05	A-1.05	A-1.06	231.88	81.67	36" RCP	0.0120	926.40	923.52	13.95	12.15	2.29	3.02	0.12	0.35	0.24	926.64	923.20	920.60	
A-1.06	A-1.06	A-1.07	81.26	86.37	36" RCP	0.0130	923.32	922.02	12.15	13.53	2.84	2.29	0.08	0.19	0.20	923.52	920.50	919.40	
A-1.07	A-1.07	A-1.08	205.95	136.01	5' x 3' CBC	0.0060	918.29	917.09	13.53	9.07	1.28	2.84	0.10	0.27	0.12	918.42	914.30	913.30	
A-1.08	A-1.08	A-1.09	50.77	138.81	5' x 3' CBC	0.0060	916.88	916.57	9.07	9.25	1.33	1.28	0.16	0.21	0.22	917.09	913.30	913.05	
A-1.09	A-1.09	A-1.10	117.94	138.48	5' x 3' CBC	0.0060	916.55	915.84	9.25	9.23	1.32	1.33	0.01	0.01	0.01	916.57	913.05	912.46	
A-1.10	A-1.10	A-1.11	19.96	137.70	5' x 3' CBC	0.0060	915.60	915.48	9.23	9.18	1.31	1.32	0.18	0.24	0.24	915.84	912.46	912.36	
A-1.11	A-1.11	A-1.12	17.71	137.57	5' x 3' CBC	0.0050	915.23	915.14	9.18	9.17	1.31	1.31	0.18	0.24	0.26	915.48	912.36	912.27	
A-1.12	A-1.12	A-1-13	352.45	140.43	5' x 3' CBC	0.0130	913.91	909.42	9.17	15.31	3.64	1.31	0.08	0.11	0.12	914.02	911.00	906.00	
A-1-13	A-1-13	A-1.13	8.92	157.21	5' x 3' CBC	0.0080	909.28	909.21	9.17	10.48	1.71	1.31	0.08	0.11	0.14	909.42	905.90	905.80	
A-1.13	A-1.13	A-1.14	6.08	184.99	6' x 3' CBC	0.0070	909.09	909.04	15.31	10.28	1.64	3.64	0.07	0.27	0.12	909.21	905.70	905.60	
A-1.14	A-1.14	A-1.15	20.00	184.94	6' x 3' CBC	0.0070	908.75	908.61	10.28	10.27	1.64	1.64	0.18	0.30	0.30	909.04	905.60	905.30	
A-1.15	A-1.15	A-1.16	111.01	184.79	6' x 3' CBC	0.0090	908.30	907.26	10.27	16.73	4.35	1.64	0.19	0.31	0.31	908.61	905.30	903.60	
A-1.16	A-1.16	A-1.17	121.66	184.26	6' x 3' CBC	0.0070	907.10	906.26	16.73	10.24	1.63	4.35	0.10	0.43	0.16	907.26	903.60	902.60	
A-1.17	A-1.17	A-1.18	51.09	183.33	6' x 3' CBC	0.0070	906.14	905.79	10.24	10.18	1.61	1.63	0.08	0.13	0.13	906.26	902.60	901.88	
A-1.18	A-1.18	A-1.19	33.14	220.93	6' x 3' CBC	0.0100	906.39	906.07	10.18	12.27	2.34	1.61	0.08	0.50	0.20	905.99	901.88	901.78	
A-1.19	A-1.19	A-1.20	8.25	226.86	6' x 3' CBC	0.0100	906.01	905.92	12.27	12.60	2.47	2.34	0.08	0.50	0.20	906.20	901.78	901.76	
A-1.20	A-1.20	A-1.21	7.46	226.79	6' x 3' CBC	0.0100	905.92	905.84	12.60	12.60	2.47	2.47	0.00	0.00	0.00	905.92	901.76	901.70	1
A-1.21	A-1.21	A-1.22	59.05	227.12	6' x 3' CBC	0.0100	905.64	905.03	12.60	12.62	2.47	2.47	0.08	0.50	0.20	905.84	901.70	900.74	1
A-1.22	A-1.22	A-1-17	8.97	228.21	6' x 3' CBC	0.0100	904.98	904.88	12.62	12.68	2.50	2.47	0.09	0.50	0.21	905.19	900.74	900.62	1
A-1.22.1	A-1-17	A-1.23	15.52	231.02	6' x 3' CBC	0.0110	905.48	905.31	12.68	12.83	2.56	2.50	0.08	0.50	0.20	905.09	900.62	900.50	1
A-1.23	A-1.23	A-1.24	86.76	230.90	6' x 3' CBC	0.0110	905.35	904.42	12.83	12.83	2.56	2.56	0.10	0.26	0.26	905.57	900.50	899.91	1
A-1.24	A-1.24	A-1.25	16.61	231.31	6' x 3' CBC	0.0110	904.56	904.38	12.83	12.85	2.56	2.56	0.09	0.50	0.23	904.65	899.91	899.79	1
A-1.25	A-1.25	A-1.26	158.90	231.18	6' x 3' CBC	0.0110	903.80	902.10	12.85	12.84	2.56	2.56	0.26	0.67	0.67	904.47	899.79	898.71	1
A-1.26	A-1.26	A-1-OUT	3.11	229.93	6' x 3' CBC	0.0110	901.71	901.68	12.84	12.77	2.53	2.56	0.15	0.38	0.38	902.10	898.71	898.68	1, 4
A-2.1	A-2.1	A-2.2	145.55	3.61	18" RCP	0.0190	938.23	935.62	12.77	8.65	1.16	2.53	0.54	1.36	0.15	938.38	937.50	932.90	
A-2.2	A-2.2	A-2.3	170.79	9.75	18" RCP	0.0090	935.37	933.90	8.65	5.52	0.47	1.16	0.36	0.42	0.17	935.54	932.80	931.20	
A-2.3	A-2.3	A-2.4	55.78	17.81	24" RCP	0.0050	933.77	933.48	5.52	5.67	0.50	0.47	0.25	0.12	0.12	933.90	929.90	929.46	
A-2.4	A-2.4	A-2.5	78.08	22.11	24" RCP	0.0080	933.24	932.60	5.67	7.04	0.77	0.50	0.32	0.16	0.24	933.48	929.46	928.84	
A-2.5	A-2.5	A-2.6	105.15	23.86	24" RCP	0.0110	932.36	931.19	7.04	7.60	0.90	0.77	0.21	0.16	0.19	932.55	928.84	928.00	
A-2.6	A-2.6	A-1.04	48.93	26.81	30" RCP	0.0040	930.89	930.69	7.60	5.46	0.46	0.90	0.62	0.56	0.29	931.18	927.40	927.20	
A-3.1	A-3.1	A-3.2	37.08	46.26	36" RCP	0.0040	921.23	921.08	5.46	6.54	0.66	0.46	1.13	0.52	0.75	921.55	915.60	915.40	
A-3.2	A-3.2	A-3.3	188.61	51.76	36" RCP	0.0050	920.95	919.98	6.54	7.32	0.83	0.66	0.16	0.11	0.13	921.08	915.30	914.70	
A-3.3	A-3.3	A-1.07	41.79	51.20	36" RCP	0.0050	919.37	919.16	7.32	7.24	0.81	0.83	0.75	0.62	0.61	919.98	914.60	914.40	
A-3-01	A-3-01	A-4-01	248.22	5.99	24" RCP	0.0180	918.16	913.96	7.24	8.32	1.07	0.81	1.00	0.81	0.00	918.16	917.29	912.24	1
A-4-01	A-4-01	A-4-02	35.32	20.72	27" RCP	0.0050	913.96	913.90	8.32	7.03	0.77	1.07	1.00	1.07	0.00	913.96	912.24	912.01	1
A-4-02	A-4-02	A-4-02.1	86.43	30.59	30" RCP	0.0180	913.90	910.73	7.03	13.74	2.93	0.77	1.00	0.77	0.00	913.90	912.01	909.51	1
A-4-02.1	A-4-02.1	A-1.13	66.39	30.52	30" RCP	0.0250	911.39	910.04	13.74	14.71	3.36	2.93	1.00	2.93	0.00	911.39	909.51	907.54	1

NOTES:

INLET AND STORM DRAIN CALCULATIONS WERE COMPLETED USING BENTLEY STORMCAD V8I.

1. EXISTING STRUCTURE
2. INLET CALCULATION REPRESENTS MULTIPLE INLET STRUCTURES ACTING TOGETHER HYDRAULICALLY AT A LOW POINT.
3. BYPASS FLOW LEAVES THE SYSTEM.
4. TAILWATER SET TO SOFFIT OF PIPE.

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL
STORM DRAIN HYDRAULIC DATA

CITY OF AUSTIN FOUNDED 1839

NOTES	NAME	DATE
SURVEY BY		
DRAWN BY	MB	
CHECKED BY	DC	
DESIGNED BY	TJK	
REVIEWED BY		

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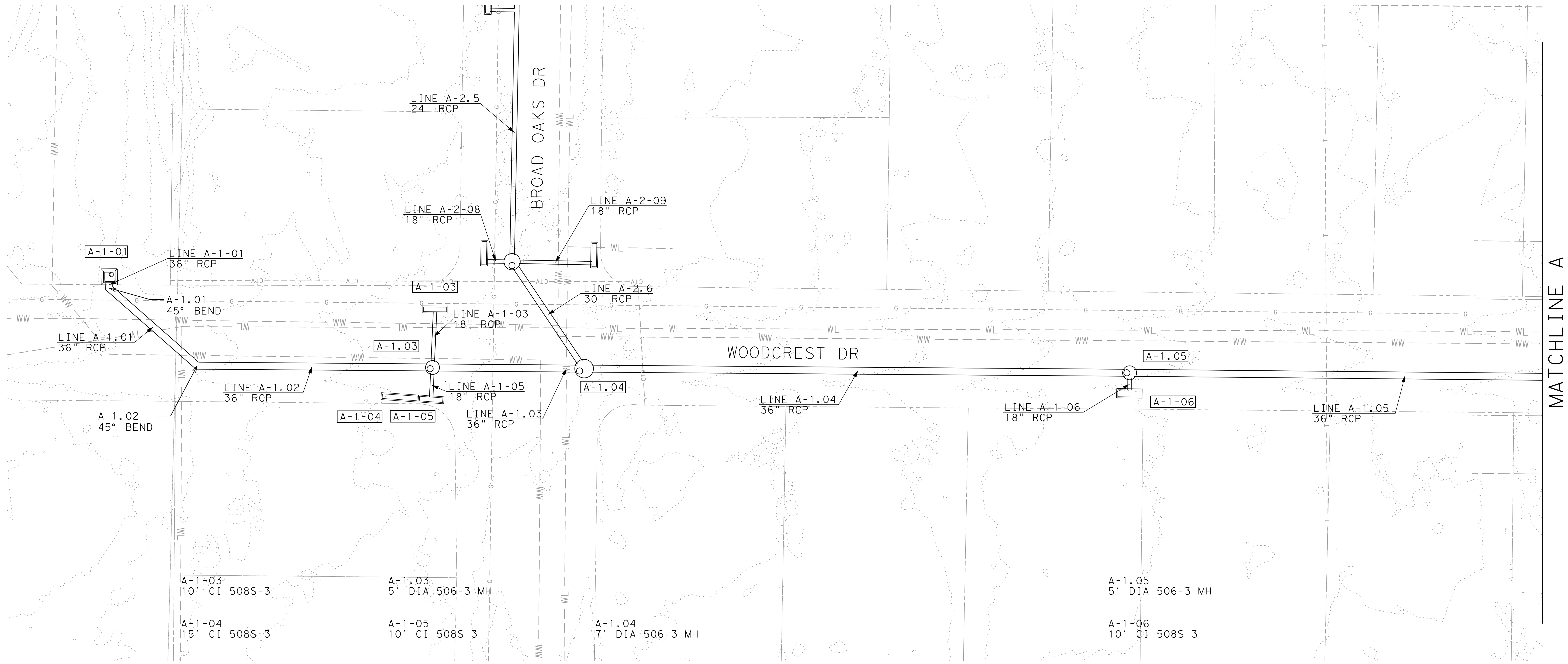
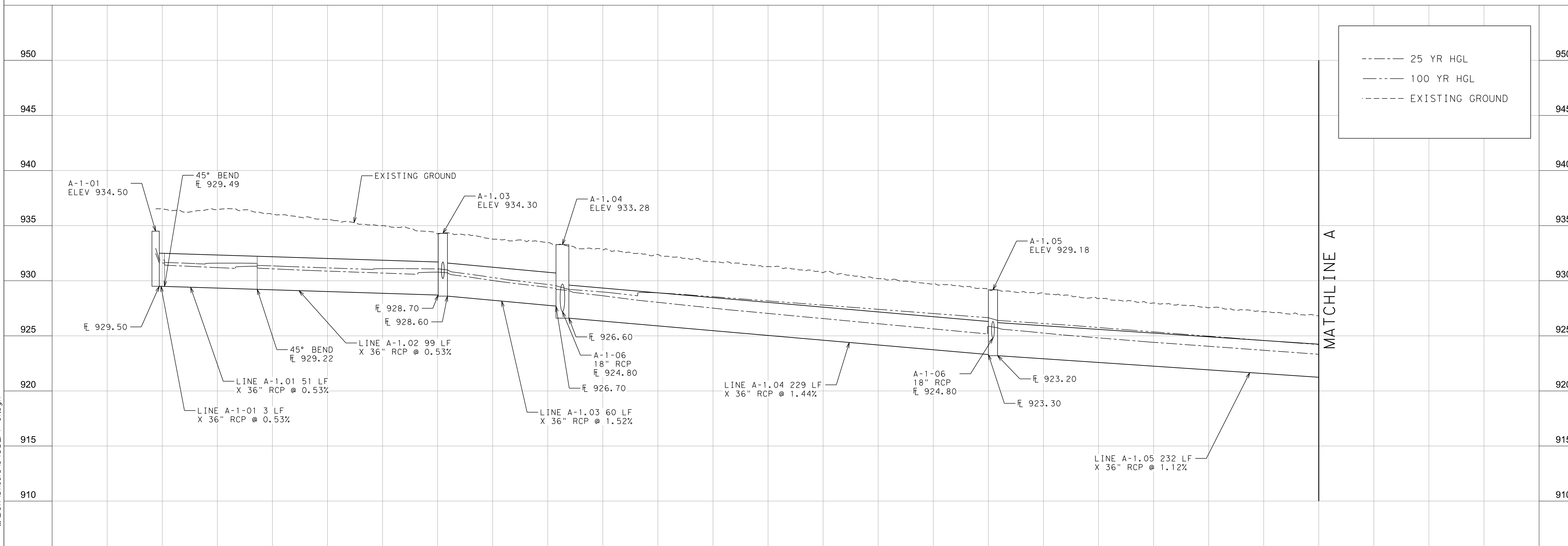


LEGEND

PROPOSED PIPELINE
ROW
PROPERTY LINE
EXISTING EASEMENT
EXISTING WATERLINE
EXISTING WASTEWATER LINE
EXISTING GROUND CONTOUR

30%

HORIZONTAL SCALE IN FEET
0 30 60
0 5 10
VERTICAL SCALE IN FEET



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WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRIVE
STORM DRAIN LAYOUT SHEET 1 OF 7

CITY OF AUSTIN FOUNDED 1839

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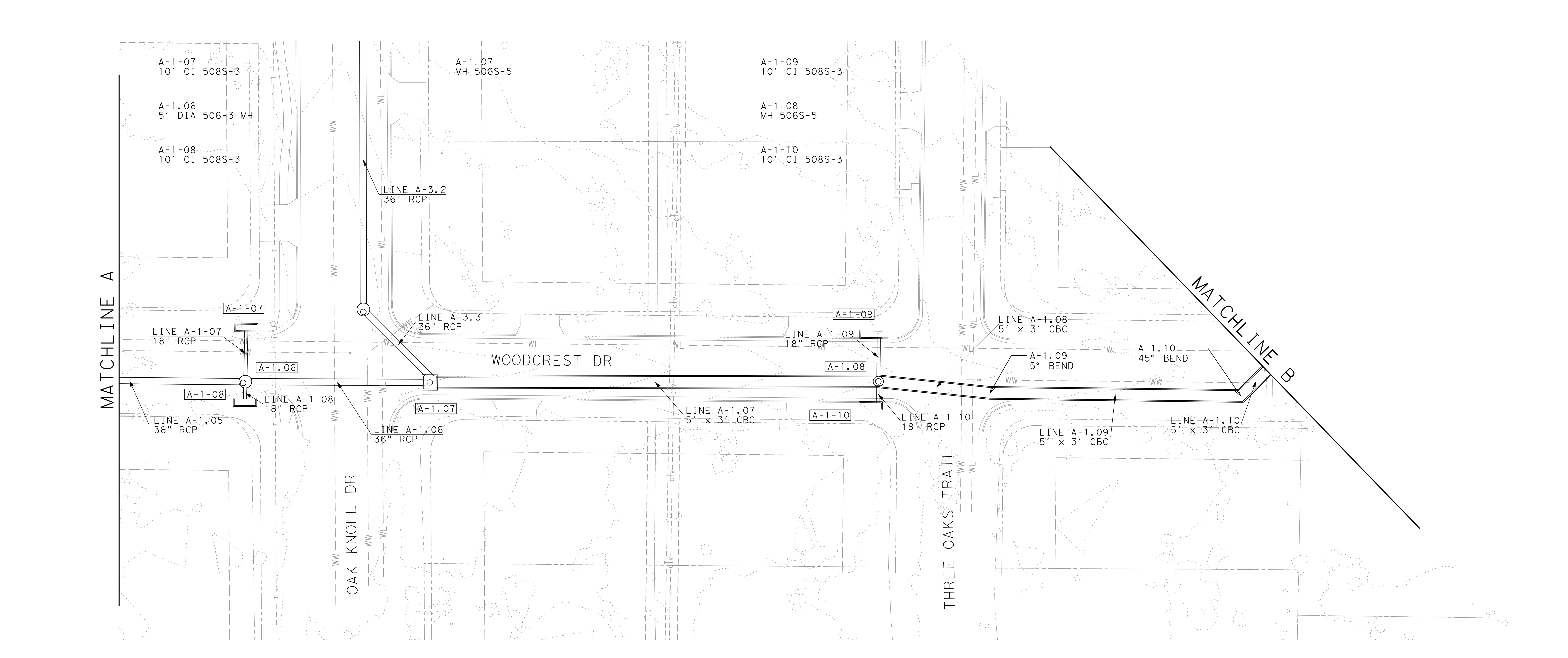
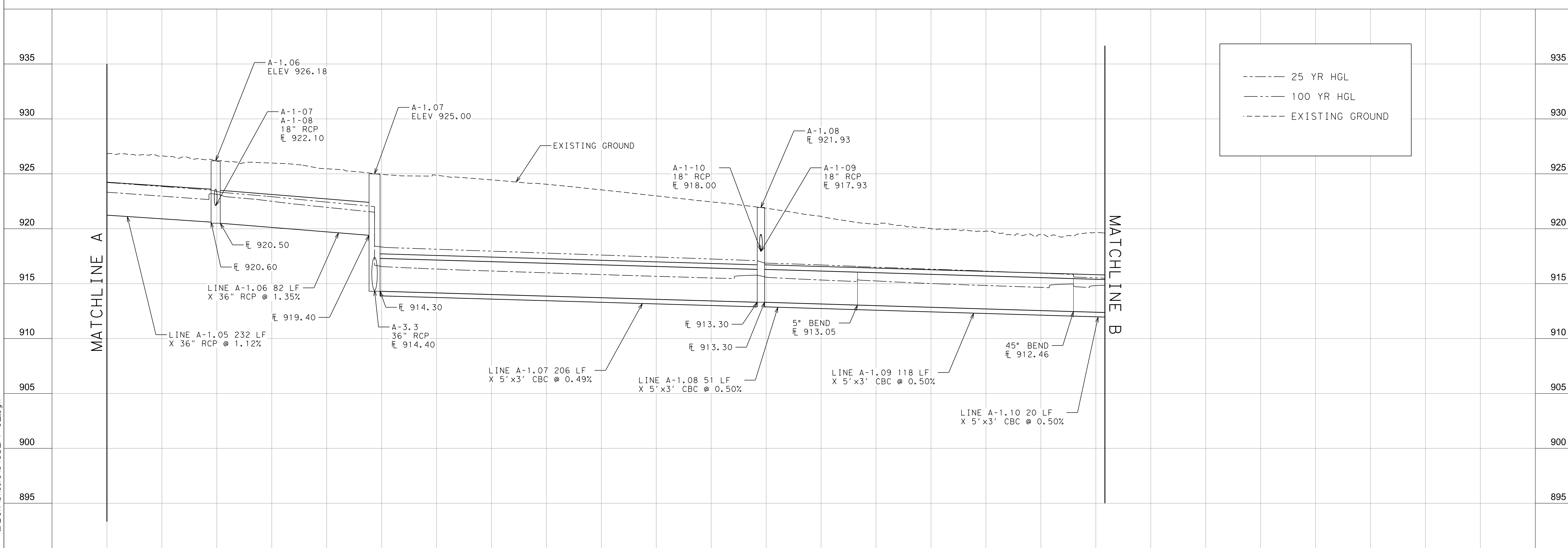
LEGEND

30%

- PROPOSED PIPELINE
- ROW
- PROPERTY LINE
- EXISTING EASEMENT
- EXISTING WATERLINE
- EXISTING WASTEWATER LINE
- EXISTING GROUND CONTOUR





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WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRIVE
STORM DRAIN LAYOUT SHEET 2 OF 7

CITY OF AUSTIN FOUNDED 1839

NOTES	NAME	DATE
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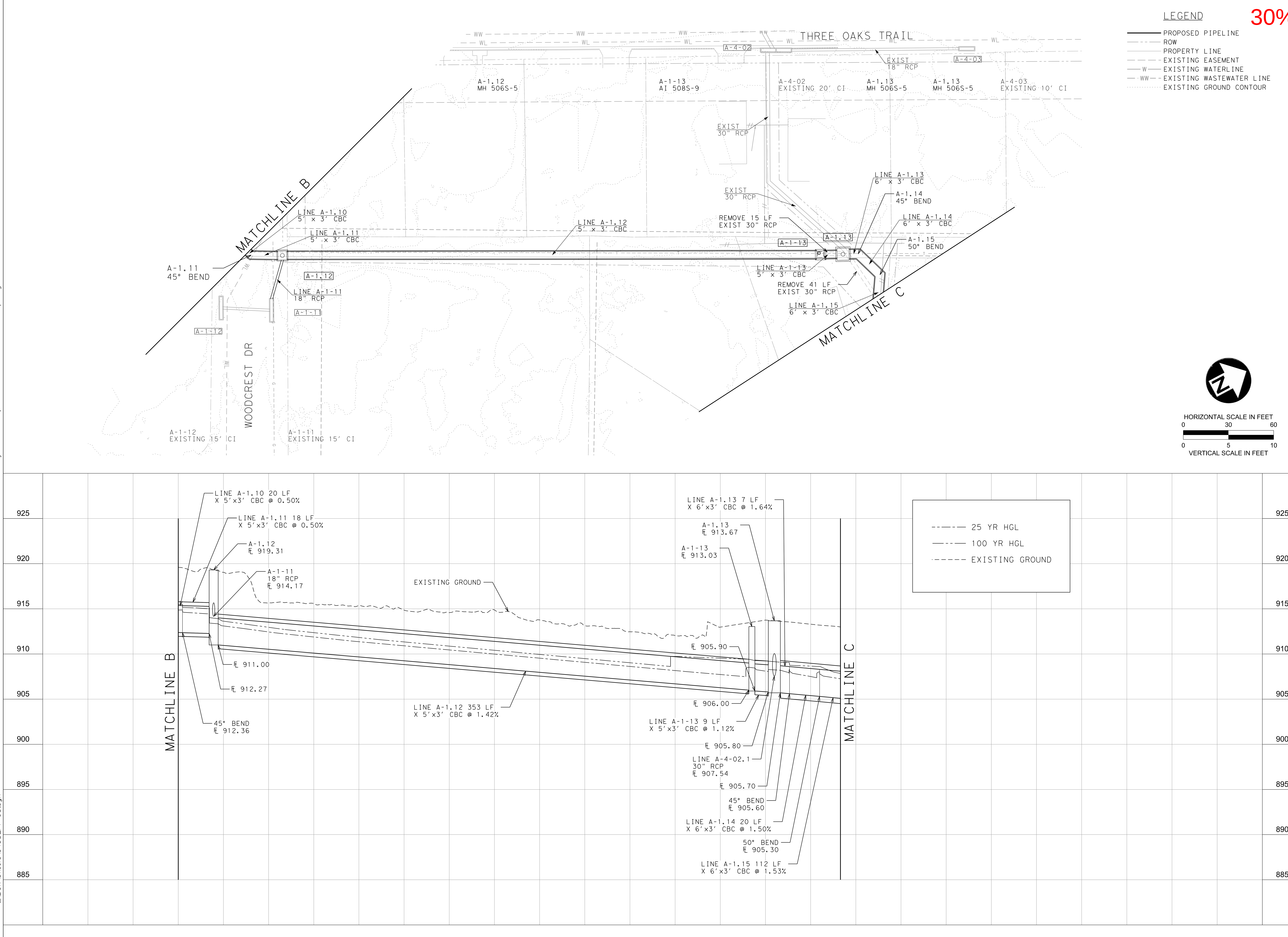

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WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRIVE
STORM DRAIN LAYOUT SHEET 3 OF 7

CITY OF AUSTIN FOUNDED 1839

NOTES	NAME	DATE
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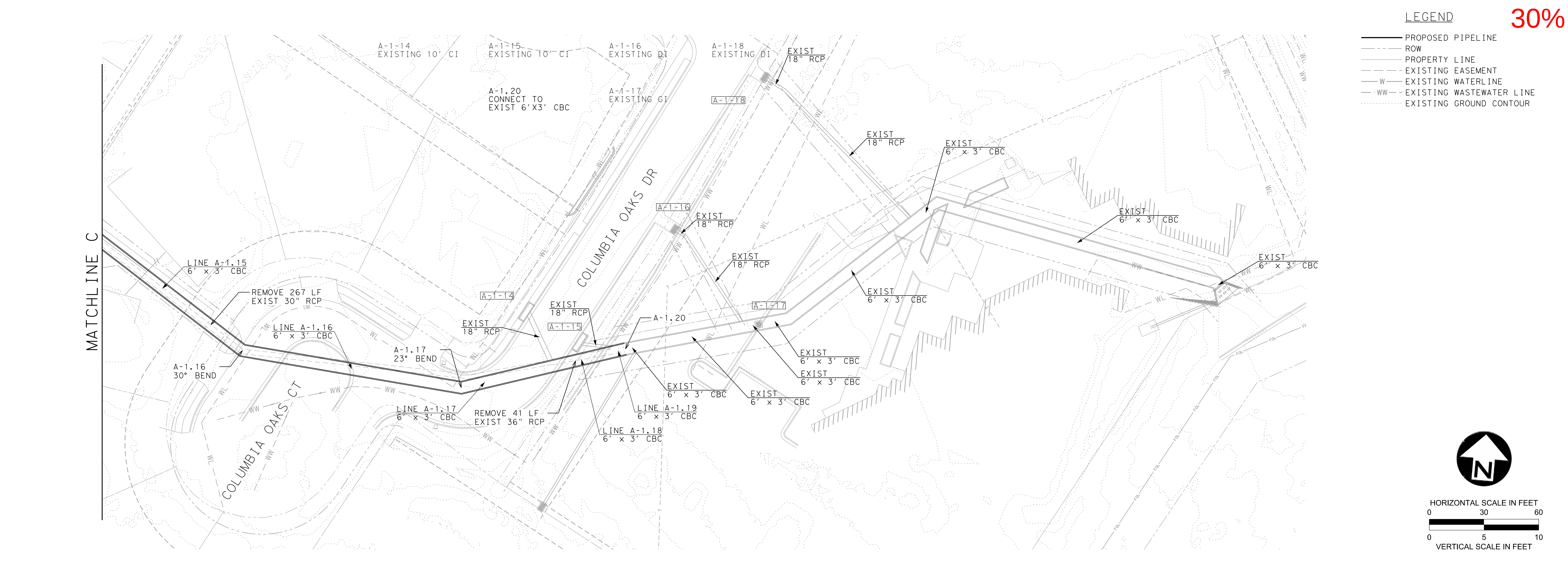

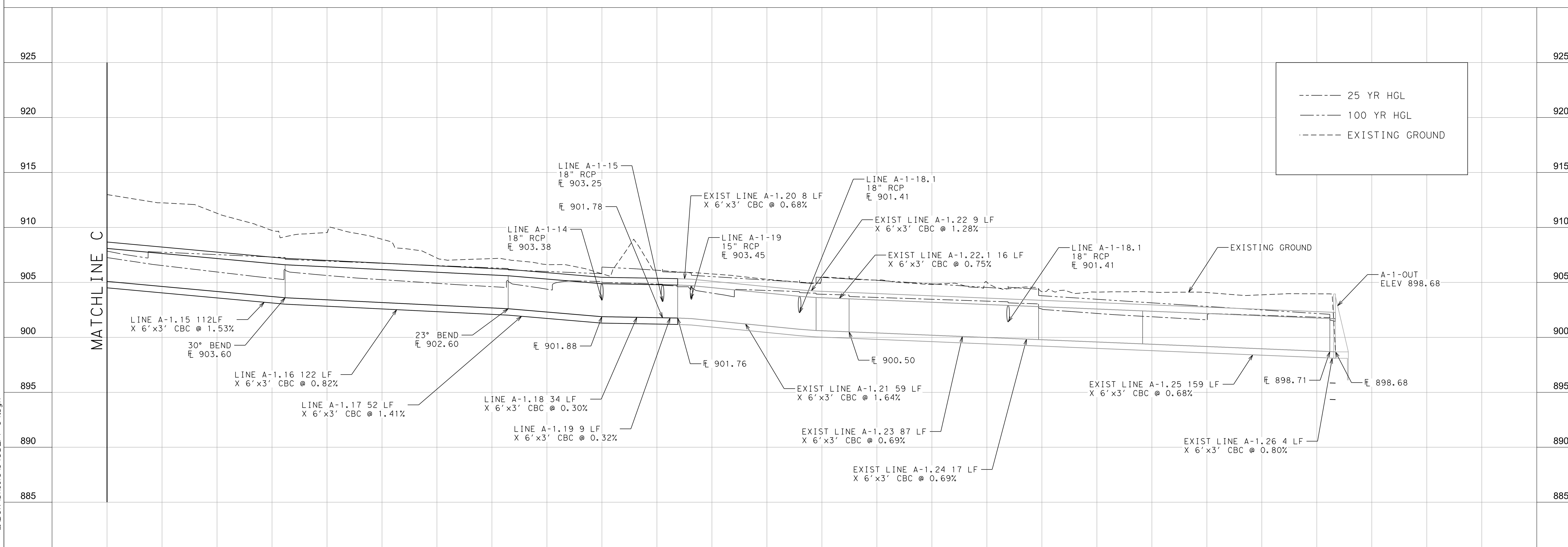

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRIVE
STORM DRAIN LAYOUT SHEET 4 OF 7

NOTES	NAME	DATE
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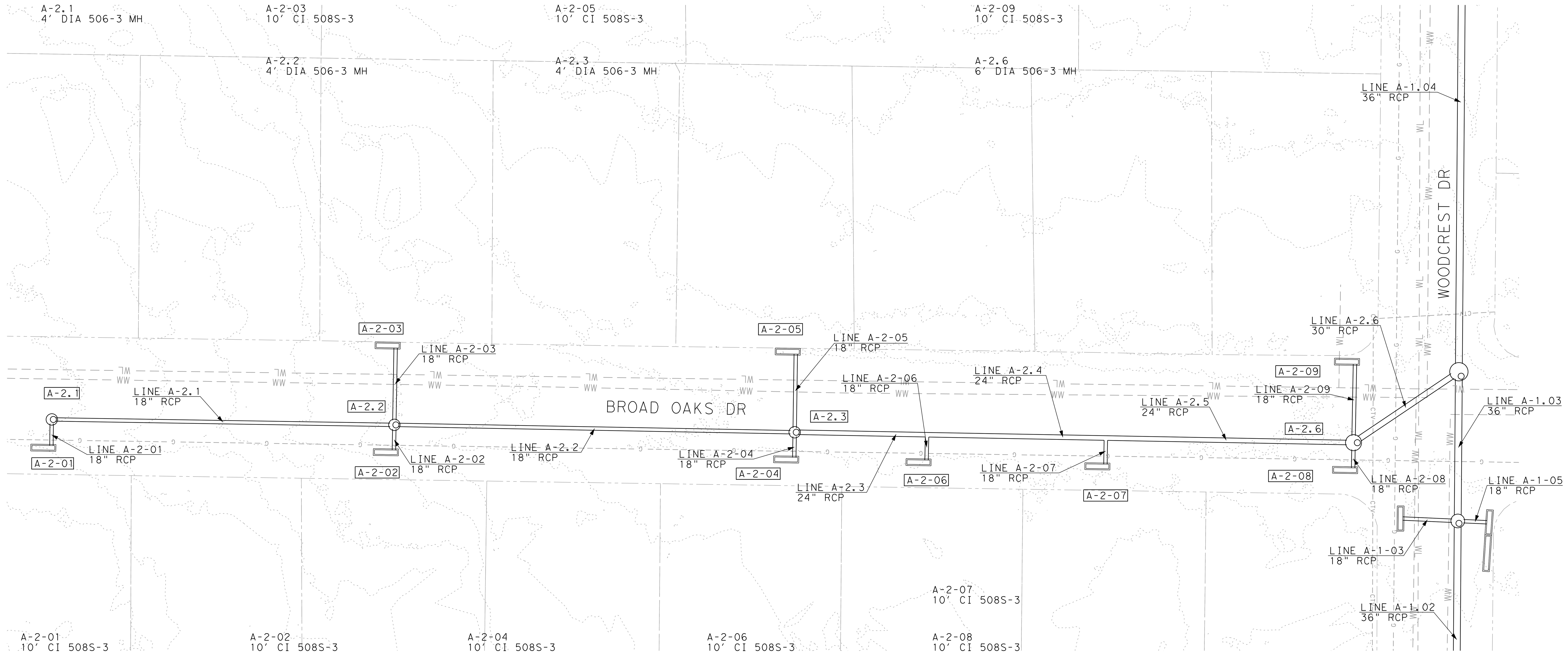
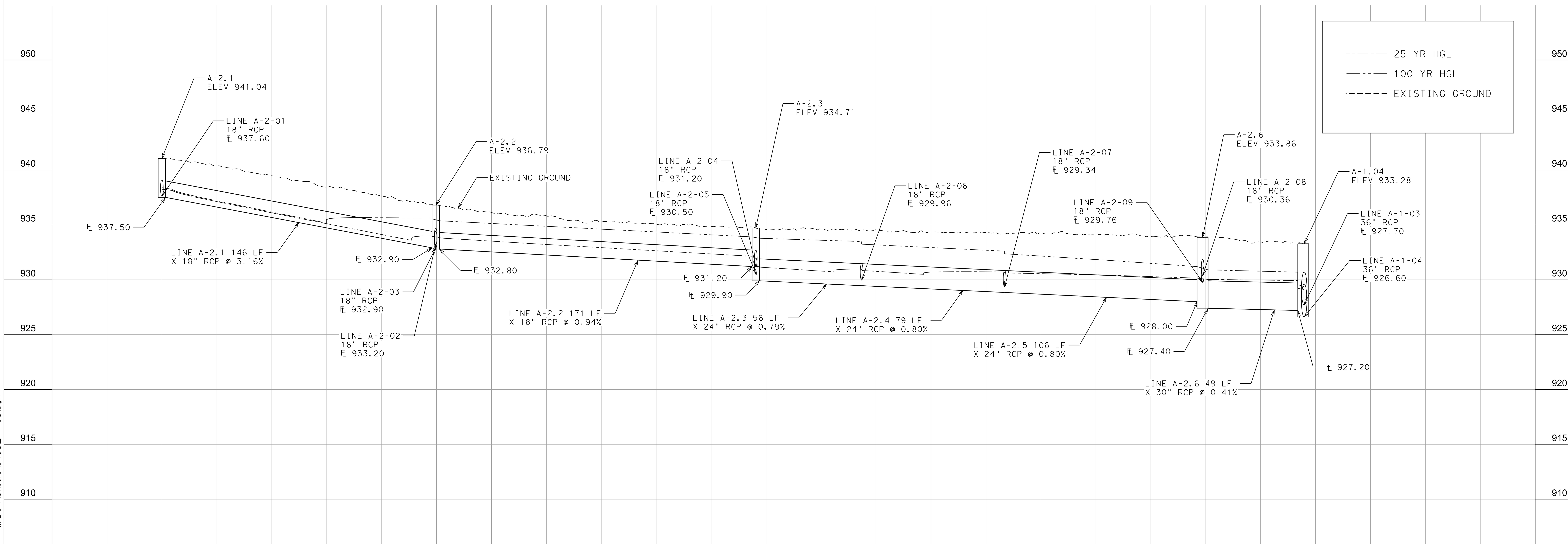
LEGEND

- PROPOSED PIPELINE
- ROW
- PROPERTY LINE
- EXISTING EASEMENT
- W — EXISTING WATERLINE
- WW — EXISTING WASTEWATER LINE
- EXISTING GROUND CONTOUR



HORIZONTAL SCALE IN FEET
0 30 60
0 5 10
VERTICAL SCALE IN FEET



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WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRIVE
STORM DRAIN LAYOUT SHEET 5 OF 7

CITY OF AUSTIN FOUNDED 1839

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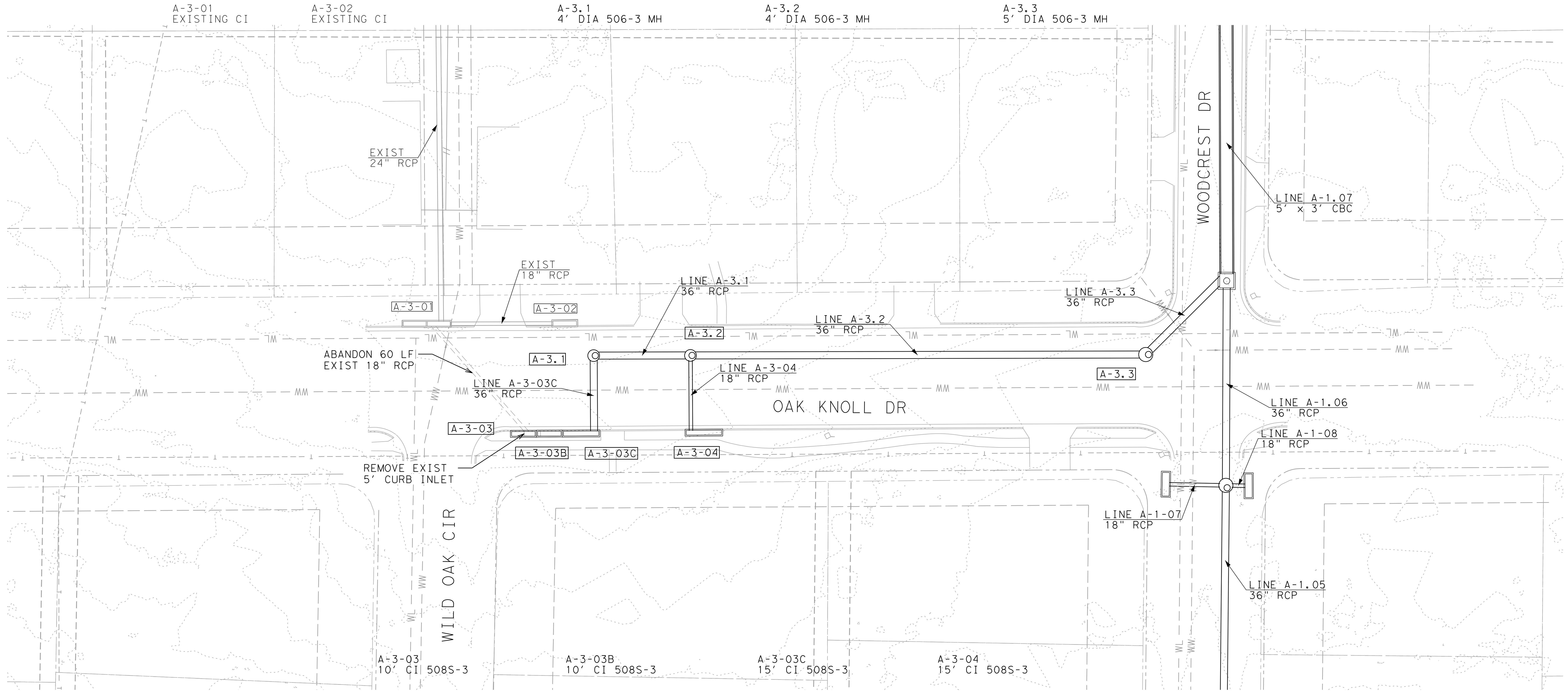
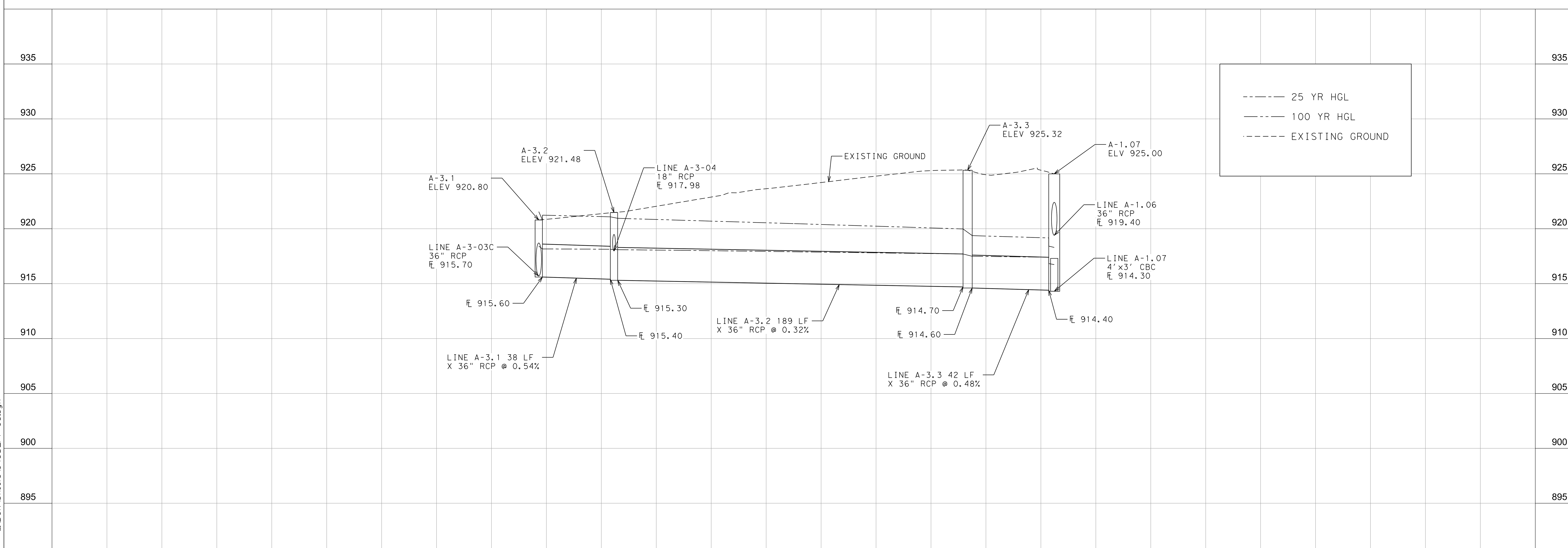
LEGEND

PROPOSED PIPELINE
ROW
PROPERTY LINE
EXISTING EASEMENT
EXISTING WATERLINE
EXISTING WASTEWATER LINE
EXISTING GROUND CONTOUR



HORIZONTAL SCALE IN FEET
0 30 60
0 5 10
VERTICAL SCALE IN FEET



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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRIVE
STORM DRAIN LAYOUT SHEET 6 OF 7

NOTES	NAME	DATE
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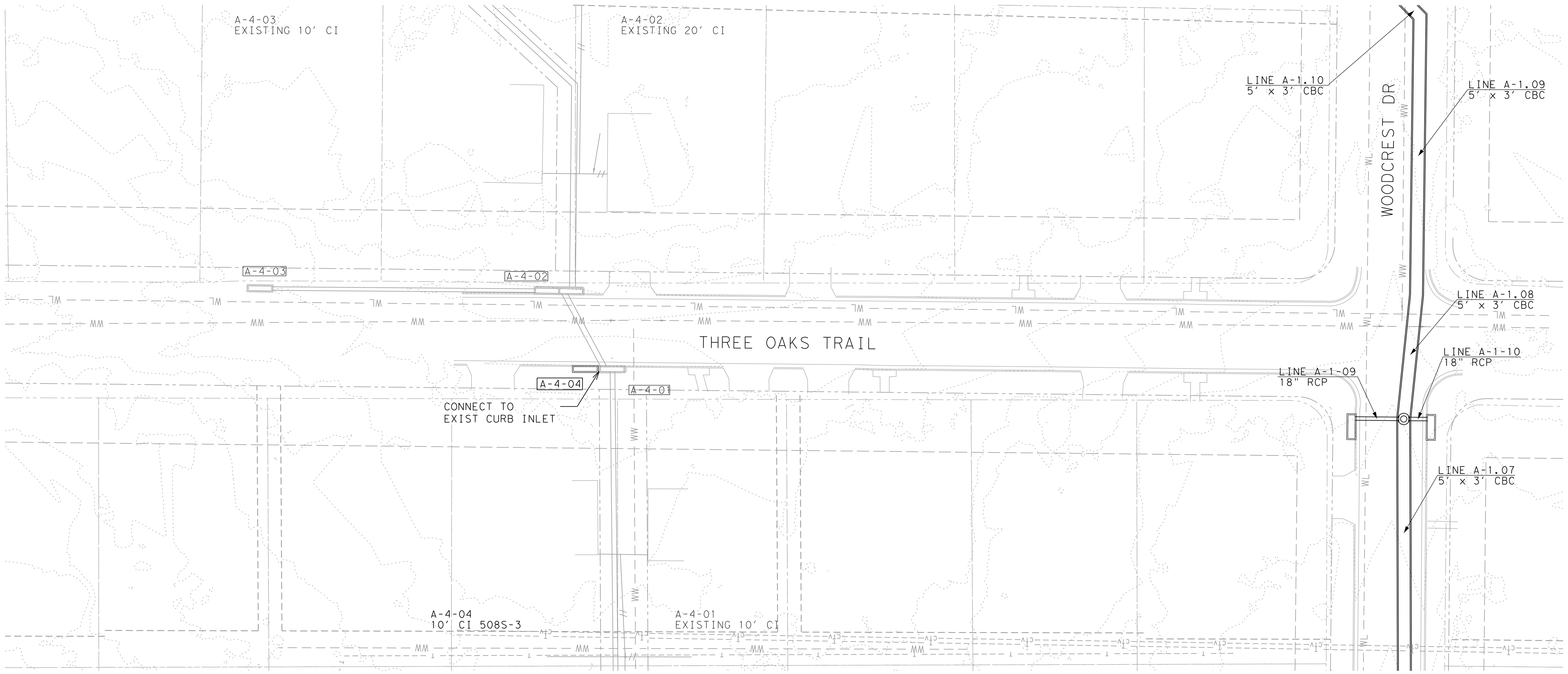

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LEGEND

- PROPOSED PIPELINE
- ROW
- PROPERTY LINE
- EXISTING EASEMENT
- W — EXISTING WATERLINE
- WW — EXISTING WASTEWATER LINE
- EXISTING GROUND CONTOUR

HORIZONTAL SCALE IN FEET: 0 30 60

VERTICAL SCALE IN FEET: 0 5 10

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

OAK KNOLL DRIVE
STORM DRAIN LAYOUT SHEET 7 OF 7

CITY OF AUSTIN FOUNDED 1839

NOTES	NAME	DATE
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LEGEND

EXISTING E.O.P.
EXISTING R.O.W.
PROPOSED E.O.P.
DRAINAGE AREA
XXX EXISTING 2-FT CONTOUR
DITCH CENTERLINE
FLOW DIRECTION
X.XX DRAINAGE AREA ID

0 75 150
HORIZONTAL SCALE IN FEET

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

BELL AVENUE
OFFSITE DRAINAGE AREA MAP

CITY OF AUSTIN FOUNDED 1839

NOTES	NAME	DATE
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LEGEND

- EXISTING E.O.P.
- EXISTING R.O.W.
- PROPOSED E.O.P.
- DRAINAGE AREA
- XXX EXISTING 1-FT CONTOUR
- DITCH CENTERLINE
- FLOW DIRECTION
- X.XX DRAINAGE AREA ID
- X.XX DRAINAGE NODE

0 30 60
HORIZONTAL SCALE IN FEET

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WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

BELL AVENUE DRAINAGE AREA MAP
1 OF 4

CITY OF AUSTIN FOUNDED 1839

NOTES	NAME	DATE
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8911 N. CAPITAL OF TEXAS HWY
BUILDING 2, SUITE 2300
AUSTIN, TX 78759

K·FRIESE + ASSOCIATES
PUBLIC PROJECT ENGINEERING
1120 S. Capital of Texas Highway
CityView 2, Suite 100
Austin, Texas 78746
TBPE Firm #6535

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LEGEND

EXISTING E.O.P.
EXISTING R.O.W.
PROPOSED E.O.P.
DRAINAGE AREA
EXISTING 1-FT CONTOUR
DITCH CENTERLINE
FLOW DIRECTION
X.XX DRAINAGE AREA ID
X.XX DRAINAGE NODE

REV NO.	BY	DATE	REVISION DESCRIPTION

PRELIMINARY

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

BELL AVENUE DRAINAGE AREA MAP
2 OF 4

NOTES	NAME	DATE
SURVEY BY		
DRAWN BY	MB	
CHECKED BY	DC	
DESIGNED BY	TJK	
REVIEWED BY		

Lockwood, Andrews & Newnam, Inc.
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LEGEND

EXISTING E.O.P.
EXISTING R.O.W.
PROPOSED E.O.P.
DRAINAGE AREA
XXX EXISTING 1-FT CONTOUR
DITCH CENTERLINE
FLOW DIRECTION
X.XX DRAINAGE AREA ID
X.XX DRAINAGE NODE

0 30 60
HORIZONTAL SCALE IN FEET

REV NO.	BY	DATE	REVISION DESCRIPTION

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

BELL AVENUE DRAINAGE AREA MAP
3 OF 4

NOTES	NAME	DATE
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CHECKED BY	DC	
DESIGNED BY	TJK	
REVIEWED BY		

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LEGEND

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EXISTING E.O.P.
EXISTING R.O.W.
PROPOSED E.O.P.
DRAINAGE AREA
EXISTING 1-FT CONTOUR
DITCH CENTERLINE
FLOW DIRECTION
X.XX DRAINAGE AREA ID
X.XX DRAINAGE NODE

0 30 60
HORIZONTAL SCALE IN FEET

REV NO.	BY	DATE	REVISION DESCRIPTION

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

BELL AVENUE DRAINAGE AREA MAP
4 OF 4

NOTES	NAME	DATE
SURVEY BY		
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DESIGNED BY	TJK	
REVIEWED BY		

Lockwood, Andrews & Newnam, Inc.
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AUSTIN, TX 78759

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DRAINAGE AREA CALCULATIONS

AREA ID	AREA (AC)	TC CALCULATED (MIN)	TC USED (MIN)	C_{25}	I_{25} (IN/HR)	Q_{25} (CFS)	C_{100}	I_{100} (IN/HR)	Q_{100} (CFS)	NOTES
B-1-01	2.16	4.2	5.0	0.68	10.10	14.9	0.76	12.50	20.7	
B-1-02	27.00	35.1	35.1	0.60	4.48	73.1	0.68	5.79	107.2	
B-1-03	0.72	1.4	5.0	0.74	10.10	5.5	0.82	12.50	7.5	
B-1-05	0.22	2.0	5.0	0.62	10.10	1.4	0.70	12.50	1.9	
B-1-06	4.11	13.0	13.0	0.59	7.65	18.8	0.67	9.83	27.3	
B-1-07	2.38	21.6	21.6	0.52	6.02	7.5	0.59	7.81	11.0	
B-1-08	0.91	16.1	16.1	0.51	6.87	3.3	0.59	8.93	4.9	
B-1-09	1.89	15.0	15.0	0.52	7.04	6.9	0.59	9.16	10.3	
B-1-10	2.25	11.0	11.0	0.54	8.26	10.1	0.61	10.50	14.5	
B-1-11	0.59	3.0	5.0	0.63	10.10	3.8	0.70	12.50	5.3	
B-1-12	0.08	0.8	5.0	0.81	10.10	0.7	0.89	12.50	0.9	
B-2-01	2.47	18.3	18.3	0.63	6.53	10.2	0.71	8.48	15.0	
B-2-02	0.47	5.6	5.6	0.72	9.92	3.4	0.81	12.30	4.8	
B-2-03	0.14	14.1	14.1	0.68	7.32	0.7	0.76	9.46	1.0	
B-2-04	1.48	28.9	28.9	0.62	4.89	4.5	0.70	6.31	6.6	
B-2-05	0.02	4.2	5.0	0.58	10.10	0.1	0.66	12.50	0.1	
B-2-06	1.90	17.7	17.7	0.64	6.62	8.1	0.72	8.61	11.8	
B-2-07	0.71	5.9	5.9	0.68	9.83	4.8	0.76	12.20	6.6	
B-2-08	0.34	5.7	5.7	0.73	9.89	2.5	0.81	12.27	3.4	
B-2-09	0.08	2.2	5.0	0.70	10.10	0.6	0.78	12.50	0.8	
B-2-10	0.08	2.0	5.0	0.79	10.10	0.6	0.87	12.50	0.9	

NOTES:

INLET AND STORM DRAIN CALCULATIONS WERE COMPLETED USING BENTLEY STORMCAD V8I.

1. EXISTING STRUCTURE
2. INLET CALCULATION REPRESENTS MULTIPLE INLET STRUCTURES ACTING TOGETHER HYDRAULICALLY AT A LOW POINT.
3. BYPASS FLOW LEAVES THE SYSTEM.
4. TAILWATER SET TO SOFFIT OF PIPE.

CURB INLET CALCULATIONS (25-YR)

INLET ID	TYPE	DRAINAGE AREA ID	DRAINAGE AREA FLOW (CFS)	CARRY-OVER FLOW Q_{PASS} (CFS)	TOTAL RUN-OFF Q_A (CFS)	PROFILE TYPE	PROFILE SLOPE S_L (%)	GUTTER DEPRESSION A (FT)	PONDED DEPTH Y_0 (FT)	ALLOWABLE PONDED WIDTH (FT)	PONDED WIDTH T (FT)	CLOG REDUCTION FACTOR	Q_A/L_A	L_A (FT)	INLET LENGTH L (FT)	L/L_A	A/Y_0	Q/Q_A	Q (CFS)	BYPASS FLOW Q_{PASS} (CFS)	BYPASS INLET ID	NOTES
B-1-05	AI 508S-9	B-1-05	1.38	0.00	1.38	In Sag	N/A	0.17	0.09	13.0	1.3	N/A	N/A	N/A	16	N/A	1.86	1.00	1.38	N/A	N/A	
B-1-06	AI 508S-9	B-1-06	18.79	0.00	18.79	In Sag	N/A	0.17	0.54	8.0	2.1	N/A	N/A	N/A	16	N/A	0.31	1.00	18.79	N/A	N/A	
B-1-07	AI 508S-9	B-1-07	7.50	0.00	7.50	In Sag	N/A	0.17	0.29	8.0	1.2	N/A	N/A	N/A	16	N/A	0.58	1.00	7.50	N/A	N/A	
B-1-08	AI 508S-9	B-1-08	3.25	0.00	3.25	In Sag	N/A	0.17	0.17	8.0	0.8	N/A	N/A	N/A	16	N/A	0.98	1.00	3.25	N/A	N/A	
B-1-09	AI 508S-9	B-1-09	6.94	0.00	6.94	In Sag	N/A	0.17	0.28	8.0	1.1	N/A	N/A	N/A	16	N/A	0.60	1.00	6.94	N/A	N/A	
B-1-10	AI 508S-9	B-1-10	10.11	0.02	10.12	In Sag	N/A	0.17	0.35	8.0	1.4	N/A	N/A	N/A	16	N/A	0.48	1.00	10.12	N/A	N/A	
B-1-12	CI 508S-3	B-1-12	0.65	0.00	0.65	On Grade	0.0	0.48	0.11	14.0	5.4	N/A	0	5.0	10	1.99	4.32	1.00	0.65	0.00		1, 3
B-2-01	CI 508S-3	B-2-01	10.21	0.00	10.21	On Grade	0.0	0.48	0.28	13.0	14.0	N/A	0	27.8	15	0.54	1.70	0.79	8.02	2.19	B-2-03	
B-2-02	CI 508S-3	B-2-02	3.43	0.00	3.43	On Grade	0.0	0.48	0.19	13.0	9.6	N/A	0	13.2	10	0.76	2.50	0.92	3.16	0.27	B-2-04	
B-2-03	CI 508S-3	B-2-03	0.69	2.19	2.87	On Grade	0.0	0.48	0.18	13.0	9.0	N/A	0	13.6	10	0.73	2.64	0.97	2.77	0.11	B-2-08	1
B-2-04	CI 508S-3	B-2-04	4.51	0.27	4.78	On Grade	0.0	0.48	0.29	14.0	14.3	N/A	0	11.7	10	0.85	1.64	0.97	4.62	0.16	B-2-07	1
B-2-05	CI 508S-3	B-2-05	0.09	3.07	3.17	On Grade	0.0	0.48	0.17	13.0	8.6	N/A	0	13.9	10	0.72	2.79	0.90	2.84	0.33	B-2-07	1
B-2-06	CI 508S-3	B-2-06	8.05	0.00	8.05	On Grade	0.0	0.48	0.24	13.0	12.2	N/A	0	24.0	10	0.42	1.98	0.62	4.97	3.07	B-2-05	
B-2-07	CI 508S-3	B-2-07	4.79	0.49	5.28	On Grade	0.0	0.48	0.21	14.0	10.7	N/A	0	18.1	10	0.55	2.26	0.76	4.02	1.26	B-2-09	
B-2-08	CI 508S-3	B-2-08	2.47	0.11	2.57	On Grade	0.0	0.48	0.16	14.0	8.2	N/A	0	13.2	10	0.76	2.97	0.96	2.47	0.10	B-2-10	
B-2-09	CI 508S-3	B-2-09	0.56	1.26	1.82	On Grade	0.0	0.48	0.14	14.0	7.2	N/A	0	9.6	10	1.04	3.39	1.00	1.82	0.00		3
B-2-10	Curb Cut	B-2-10	0.63	0.10	0.73	On Grade	0.0	0.48	0.10	0.0	5.1	N/A	0	11.6	5	0.43	4.80	0.97	0.71	0.02	B-1-10	1

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

BELL AVENUE
STORM DRAIN HYDRAULIC DATA

CITY OF AUSTIN FOUNDED 1839

NOTES	NAME	DATE
SURVEY BY		
DRAWN BY	MB	
CHECKED BY	DC	
DESIGNED BY	TJK	
REVIEWED BY		

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STORM DRAIN HYDRAULIC CALCULATIONS (25-YR)

LINK ID	MANHOLES/INLETS FROM	MANHOLES/INLETS TO	DIST. FEET	DISCHARGE C.F.S.	PIPE SIZE	FRICTION GRADE FT/FT	HYDR. GRADIENT UP STREAM ELEV.	HYDR. GRADIENT DOWN STREAM ELEV.	V_1 INFLOW F.P.S.	V_2 OUTFLOW F.P.S.	V_2^2 / 2g FT.	V_1^2 / 2g FT.	K_j CONST	$K_jV_1^2$ / 2g FT.	h FT.	H.G.EL. DESIGN PT. ELEV.	INV. IN FEET	INV. OUT FT/FT	NOTES
B-1-02	B-1-02	B-1.01	3.00	73.08	3' x 3' CBC	0.3170	880.14	879.45	7.64	40.62	25.62	0.91	0.70	0.63	0.92	880.19	877.50	876.50	
B-1.01	B-1.01	B-1.02	28.79	73.08	3' x 3' CBC	0.0410	879.14	878.27	40.62	22.66	7.97	25.62	0.24	6.15	0.32	879.46	876.50	874.70	
B-1.02	B-1.02	B-1.03	42.46	79.68	3' x 3' CBC	0.0270	877.50	876.37	22.66	17.09	4.54	7.97	0.55	4.40	0.77	878.27	874.70	873.54	
B-1.03	B-1.03	B-1.04	85.56	79.65	3' x 3' CBC	0.0260	876.34	874.29	17.09	17.10	4.54	4.54	0.02	0.09	0.03	876.37	873.54	871.20	
B-1.04	B-1.04	B-1.05	68.56	81.99	3' x 3' CBC	0.0270	874.05	872.20	17.10	17.20	4.59	4.54	0.16	0.74	0.23	874.29	871.20	869.33	
B-1.05	B-1.05	B-1.06	32.72	81.93	3' x 3' CBC	0.0270	872.18	871.31	17.20	17.25	4.62	4.59	0.01	0.05	0.01	872.20	869.33	868.43	
B-1.06	B-1.06	B-1.07	26.76	81.90	3' x 3' CBC	0.0100	871.28	869.80	17.25	17.20	4.59	4.62	0.02	0.09	0.03	871.31	868.43	867.70	
B-1.07	B-1.07	B-1.08	85.73	82.49	4' x 3' CBC	0.0030	870.21	870.05	17.20	8.24	1.05	4.59	0.08	0.35	0.07	870.28	867.60	867.27	
B-1.08	B-1.08	B-1.09	27.61	82.34	4' x 3' CBC	0.0030	870.04	869.99	8.24	6.86	0.73	1.05	0.01	0.01	0.01	870.05	867.27	867.17	
B-1.09	B-1.09	B-1.10	65.99	93.20	4' x 3' CBC	0.0040	869.91	869.68	6.86	7.77	0.94	0.73	0.08	0.06	0.09	869.99	867.17	866.91	
B-1.10	B-1.10	B-1.11	81.63	93.06	4' x 3' CBC	0.0040	869.65	869.16	7.77	7.75	0.93	0.94	0.02	0.02	0.02	869.68	866.91	866.60	
B-1.11	B-1.11	B-1.12	54.15	98.41	5' x 3' CBC	0.0030	869.01	868.84	7.75	6.56	0.67	0.93	0.11	0.10	0.10	869.11	866.50	866.34	
B-1.12	B-1.12	B-1.13	141.29	98.26	5' x 3' CBC	0.0030	868.83	868.41	6.56	6.55	0.67	0.67	0.01	0.01	0.01	868.84	866.34	865.91	
B-1.13	B-1.13	B-1.14	95.99	97.88	5' x 3' CBC	0.0030	868.40	867.91	6.55	6.53	0.66	0.67	0.01	0.01	0.01	868.41	865.91	865.63	
B-1.14	B-1.14	B-1.15	110.66	99.70	5' x 3' CBC	0.0030	867.81	867.85	6.53	9.06	1.27	0.66	0.08	0.06	0.10	867.91	865.50	865.02	
B-1.15	B-1.15	B-1.16	120.17	99.47	5' x 3' CBC	0.0030	867.83	867.58	9.06	9.04	1.27	1.27	0.02	0.03	0.02	867.85	865.02	864.50	
B-1.16	B-1.16	B-1.17	27.09	103.55	5' x 3' CBC	0.0030	867.51	867.41	9.04	6.90	0.74	1.27	0.10	0.13	0.08	867.58	864.40	864.32	
B-1.17	B-1.17	B-1.18	66.93	124.23	5' x 3' CBC	0.0030	867.29	867.07	6.90	8.28	1.06	0.74	0.12	0.09	0.13	867.41	864.32	864.12	
B-1.18	B-1.18	B-1.19	125.39	124.05	5' x 3' CBC	0.0030	867.06	866.41	8.28	8.27	1.06	1.06	0.01	0.01	0.01	867.07	864.12	863.74	
B-1.19	B-1.19	B-1.20	168.71	123.70	5' x 3' CBC	0.0210	865.47	857.15	8.27	21.41	7.12	1.06	0.07	0.08	0.10	865.57	862.80	855.90	
B-1.20	B-1.20	B-1.21	122.32	128.85	5' x 3' CBC	0.0190	857.54	855.27	21.41	16.53	4.24	7.12	0.07	0.48	0.09	857.64	854.80	852.50	
B-1.21	B-1.21	B-1.22	47.02	128.68	5' x 3' CBC	0.0190	855.24	854.40	16.53	16.49	4.22	4.24	0.02	0.08	0.03	855.27	852.50	851.62	
B-1.22	B-1.22	B-1.23	43.08	128.61	5' x 3' CBC	0.0190	854.36	853.59	16.49	16.45	4.20	4.22	0.03	0.13	0.04	854.40	851.62	850.82	
B-1.23	B-1.23	B-1.24	33.72	128.55	5' x 3' CBC	0.0190	853.56	852.96	16.45	16.48	4.22	4.20	0.02	0.08	0.03	853.59	850.82	850.19	
B-1.24	B-1.24	B-1.25	42.50	128.50	5' x 3' CBC	0.0180	852.93	852.35	16.48	16.45	4.20	4.22	0.02	0.08	0.03	852.96	850.19	849.40	
B-1.25	B-1.25	B-1.OUT	74.80	130.34	5' x 3' CBC	0.0180	852.16	851.00	16.45	16.56	4.26	4.20	0.14	0.57	0.19	852.35	849.40	848.00	4
B-2.01	B-2.01	B-2.02	51.87	12.54	24" RCP	0.0040	878.77	878.47	16.56	5.41	0.45	4.26	0.36	1.53	0.17	878.94	877.40	877.20	
B-2.02	B-2.02	B-2.03	101.90	12.49	24" RCP	0.0050	878.37	877.84	5.41	6.14	0.59	0.45	0.00	0.00	0.00	878.37	877.10	876.56	
B-2.03	B-2.03	B-2.04	132.86	12.41	24" RCP	0.0050	877.83	877.29	6.14	6.12	0.58	0.59	0.03	0.02	0.02	877.84	876.56	875.86	
B-2.04	B-2.04	B-2.05	45.76	14.01	24" RCP	0.0050	877.21	877.07	6.12	6.36	0.63	0.58	0.14	0.08	0.08	877.29	875.86	875.61	
B-2.05	B-2.05	B-2.06	91.82	18.97	24" RCP	0.0180	877.07	875.47	6.36	10.73	1.79	0.63	1.00	0.63	0.00	877.07	875.50	873.89	
B-2.06	B-2.06	B-2.07	113.30	18.88	24" RCP	0.0170	875.45	873.64	10.73	10.73	1.79	1.79	0.02	0.04	0.02	875.47	873.89	871.90	
B-2.07	B-2.07	B-2.08	150.55	21.95	24" RCP	0.0340	873.47	868.48	10.73	14.58	3.30	1.79	0.18	0.32	0.17	873.64	871.80	866.38	
B-2.08	B-2.08	B-1.17	29.54	22.69	24" RCP	0.0090	868.33	868.09	14.58	14.69	3.35	3.30	0.18	0.60	0.15	868.48	866.38	865.32	

NOTES:

INLET AND STORM DRAIN CALCULATIONS WERE COMPLETED USING BENTLEY STORMCAD V8I.

1. EXISTING STRUCTURE
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4. TAILWATER SET TO SOFFIT OF PIPE.

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CITY OF AUSTIN, TEXAS
WATERSHED PROTECTION DEPARTMENT

OAK KNOLL
DRAINAGE IMPROVEMENTS

BELL AVENUE
STORM DRAIN HYDRAULIC DATA

CITY OF AUSTIN FOUNDED 1839

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CHECKED BY	DC	
DESIGNED BY	TJK	
REVIEWED BY		

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TBPE Firm #6535

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STORM DRAIN HYDRAULIC CALCULATIONS (100-YR)

LINK ID	MANHOLES/INLETS FROM	TO	DIST. FEET	DISCHARGE C.F.S.	PIPE SIZE	FRICTION GRADE FT/FT	HYDR. GRADIENT UP STREAM ELEV.	DOWN STREAM ELEV.	V_1 INFLOW F.P.S.	V_2 OUTFLOW F.P.S.	$V_2^2 / 2g$ FT.	$V_1^2 / 2g$ FT.	K_j CONST	$K_jV_1^2 / 2g$ FT.	h FT.	H.G.EL. DESIGN PT. ELEV.	INV. IN FEET	INV. OUT FT/FT	NOTES
B-1-02	B-1-02	B-1.01	3.00	107.15	3' x 3' CBC	0.0790	880.50	880.25	7.24	45.81	32.59	0.81	0.70	0.57	1.54	880.80	877.50	876.50	
B-1.01	B-1.01	B-1.02	28.79	107.15	3' x 3' CBC	0.0140	880.10	879.71	45.81	11.91	2.20	32.59	0.24	7.82	0.53	880.63	876.50	874.70	
B-1.02	B-1.02	B-1.03	42.46	116.67	3' x 3' CBC	0.0160	878.94	878.25	11.91	12.96	2.61	2.20	0.71	1.56	1.85	880.79	874.70	873.54	
B-1.03	B-1.03	B-1.04	85.56	116.61	3' x 3' CBC	0.0160	878.20	876.83	12.96	12.96	2.61	2.61	0.02	0.05	0.05	878.25	873.54	871.20	
B-1.04	B-1.04	B-1.05	68.56	119.94	3' x 3' CBC	0.0170	876.71	875.55	12.96	13.33	2.76	2.61	0.24	0.64	0.67	877.39	871.20	869.33	
B-1.05	B-1.05	B-1.06	32.72	119.84	3' x 3' CBC	0.0170	875.52	874.97	13.33	13.32	2.76	2.76	0.01	0.03	0.03	875.55	869.33	868.43	
B-1.06	B-1.06	B-1.07	26.76	119.79	3' x 3' CBC	0.0170	875.13	874.68	13.32	13.31	2.75	2.76	0.02	0.06	0.06	875.02	868.43	867.70	
B-1.07	B-1.07	B-1.08	85.73	120.63	4' x 3' CBC	0.0080	874.88	874.18	13.31	10.05	1.57	2.75	0.14	0.39	0.22	874.90	867.60	867.27	
B-1.08	B-1.08	B-1.09	27.61	120.47	4' x 3' CBC	0.0080	874.17	873.94	10.05	10.04	1.57	1.57	0.01	0.02	0.02	874.18	867.27	867.17	
B-1.09	B-1.09	B-1.10	65.99	136.41	4' x 3' CBC	0.0100	874.42	873.74	10.04	11.37	2.01	1.57	0.14	0.22	0.28	874.22	867.17	866.91	
B-1.10	B-1.10	B-1.11	81.63	136.28	4' x 3' CBC	0.0100	874.37	873.53	11.37	11.36	2.00	2.01	0.02	0.04	0.04	873.78	866.91	866.60	
B-1.11	B-1.11	B-1.12	54.15	144.24	5' x 3' CBC	0.0070	873.25	872.90	11.36	9.62	1.44	2.00	0.19	0.38	0.27	873.53	866.50	866.34	
B-1.12	B-1.12	B-1.13	141.29	144.10	5' x 3' CBC	0.0070	872.88	871.96	9.62	9.61	1.43	1.44	0.01	0.01	0.01	872.90	866.34	865.91	
B-1.13	B-1.13	B-1.14	95.99	143.75	5' x 3' CBC	0.0070	871.94	871.32	9.61	9.58	1.43	1.43	0.01	0.01	0.01	871.96	865.91	865.63	
B-1.14	B-1.14	B-1.15	110.66	146.62	5' x 3' CBC	0.0070	871.10	870.35	9.58	9.77	1.48	1.43	0.14	0.20	0.21	871.32	865.50	865.02	
B-1.15	B-1.15	B-1.16	120.17	146.34	5' x 3' CBC	0.0070	870.32	869.51	9.77	9.76	1.48	1.48	0.02	0.03	0.03	870.35	865.02	864.50	
B-1.16	B-1.16	B-1.17	27.09	152.44	5' x 3' CBC	0.0070	869.29	869.10	9.76	10.16	1.60	1.48	0.13	0.20	0.22	869.51	864.40	864.32	
B-1.17	B-1.17	B-1.18	66.93	181.34	5' x 3' CBC	0.0100	868.76	868.06	10.16	12.09	2.27	1.60	0.15	0.24	0.34	869.10	864.32	864.12	
B-1.18	B-1.18	B-1.19	125.39	181.17	5' x 3' CBC	0.0100	868.04	866.74	12.09	12.08	2.27	2.27	0.01	0.02	0.02	868.06	864.12	863.74	
B-1.19	B-1.19	B-1.20	168.71	180.86	5' x 3' CBC	0.0200	865.80	857.59	12.08	24.03	8.97	2.27	0.08	0.18	0.18	865.98	862.80	855.90	
B-1.20	B-1.20	B-1.21	122.32	188.77	5' x 3' CBC	0.0180	857.80	855.55	24.03	18.39	5.25	8.97	0.07	0.64	0.17	857.97	854.80	852.50	
B-1.21	B-1.21	B-1.22	47.02	188.56	5' x 3' CBC	0.0170	855.50	854.69	18.39	18.35	5.23	5.25	0.02	0.11	0.05	855.55	852.50	851.62	
B-1.22	B-1.22	B-1.23	43.08	188.48	5' x 3' CBC	0.0170	854.62	853.87	18.35	18.30	5.20	5.23	0.03	0.16	0.07	854.69	851.62	850.82	
B-1.23	B-1.23	B-1.24	33.72	188.41	5' x 3' CBC	0.0160	853.82	853.29	18.30	18.34	5.22	5.20	0.02	0.10	0.05	853.87	850.82	850.19	
B-1.24	B-1.24	B-1.25	42.50	188.35	5' x 3' CBC	0.0110	853.24	852.76	18.34	12.56	2.45	5.22	0.02	0.10	0.05	853.29	850.19	849.40	
B-1.25	B-1.25	B-1.OUT	74.80	191.02	5' x 3' CBC	0.0190	852.40	851.00	12.56	18.42	5.27	2.45	0.14	0.35	0.36	852.76	849.40	848.00	4
B-2.01	B-2.01	B-2.02	51.87	16.77	24" RCP	0.0050	879.09	878.68	18.42	5.34	0.44	5.27	0.41	2.14	0.22	879.31	877.40	877.20	
B-2.02	B-2.02	B-2.03	101.90	16.71	24" RCP	0.0050	878.64	878.14	5.34	6.45	0.65	0.44	0.00	0.00	0.00	878.64	877.10	876.56	
B-2.03	B-2.03	B-2.04	132.86	16.60	24" RCP	0.0050	878.12	877.66	6.45	6.43	0.64	0.65	0.03	0.02	0.02	878.14	876.56	875.86	
B-2.04	B-2.04	B-2.05	45.76	18.78	24" RCP	0.0060	877.55	877.27	6.43	6.55	0.67	0.64	0.16	0.10	0.11	877.66	875.86	875.61	
B-2.05	B-2.05	B-2.06	91.82	25.24	24" RCP	0.0180	877.27	875.68	6.55	11.42	2.03	0.67	1.00	0.67	0.00	877.27	875.50	873.89	
B-2.06	B-2.06	B-2.07	113.30	25.13	24" RCP	0.0150	875.66	874.12	11.42	11.41	2.02	2.03	0.02	0.04	0.02	875.68	873.89	871.90	
B-2.07	B-2.07	B-2.08	150.55	29.74	24" RCP	0.0150	873.83	871.62	11.41	9.47	1.39	2.02	0.20	0.41	0.28	874.12	871.80	866.38	
B-2.08	B-2.08	B-1.17	29.54	31.31	24" RCP	0.0160	871.37	870.89	9.47	9.97	1.54	1.39	0.33	0.46	0.51	871.88	866.38	865.32	

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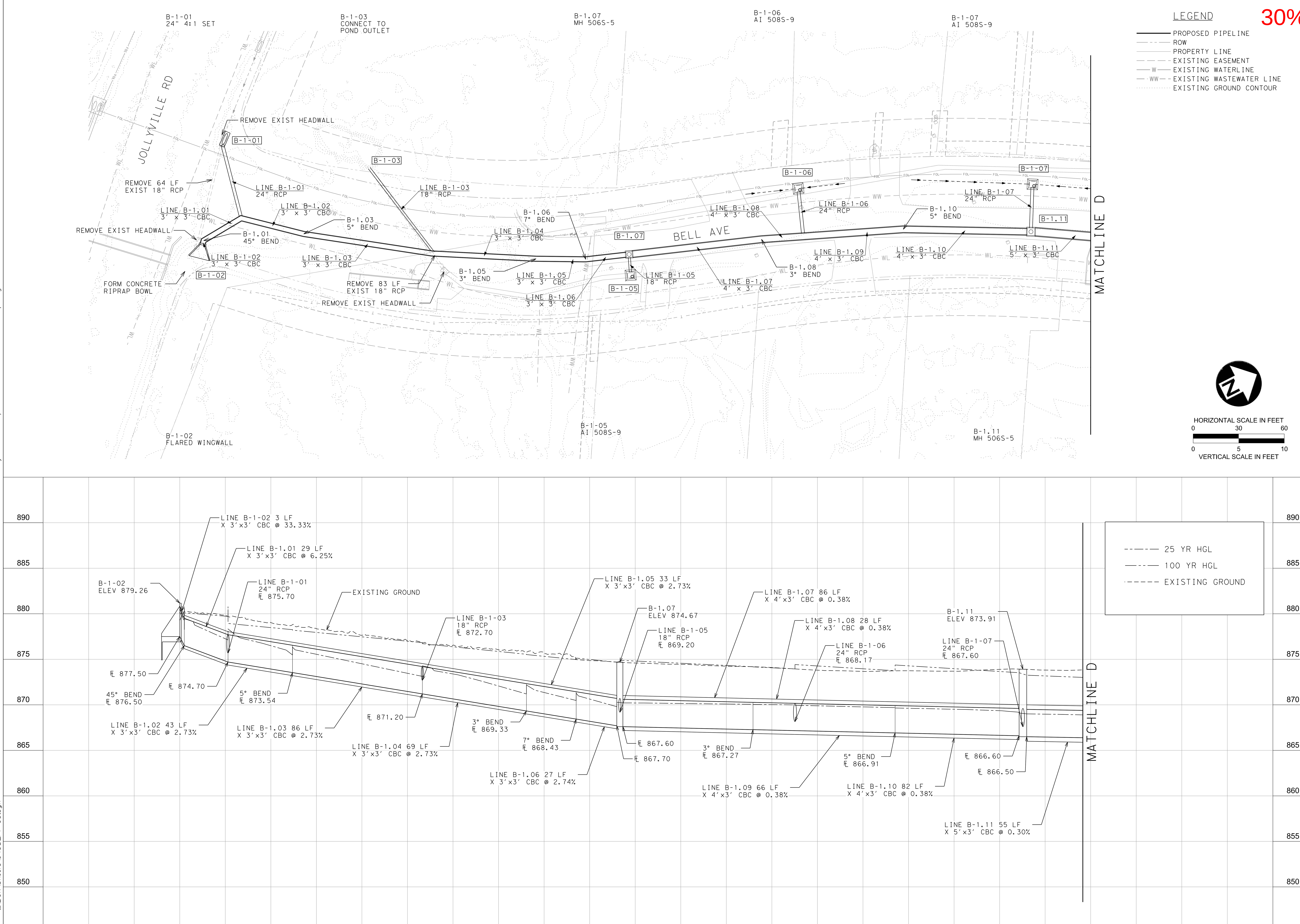

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BELL AVENUE STORM DRAIN LAYOUT SHEET 1 OF 4

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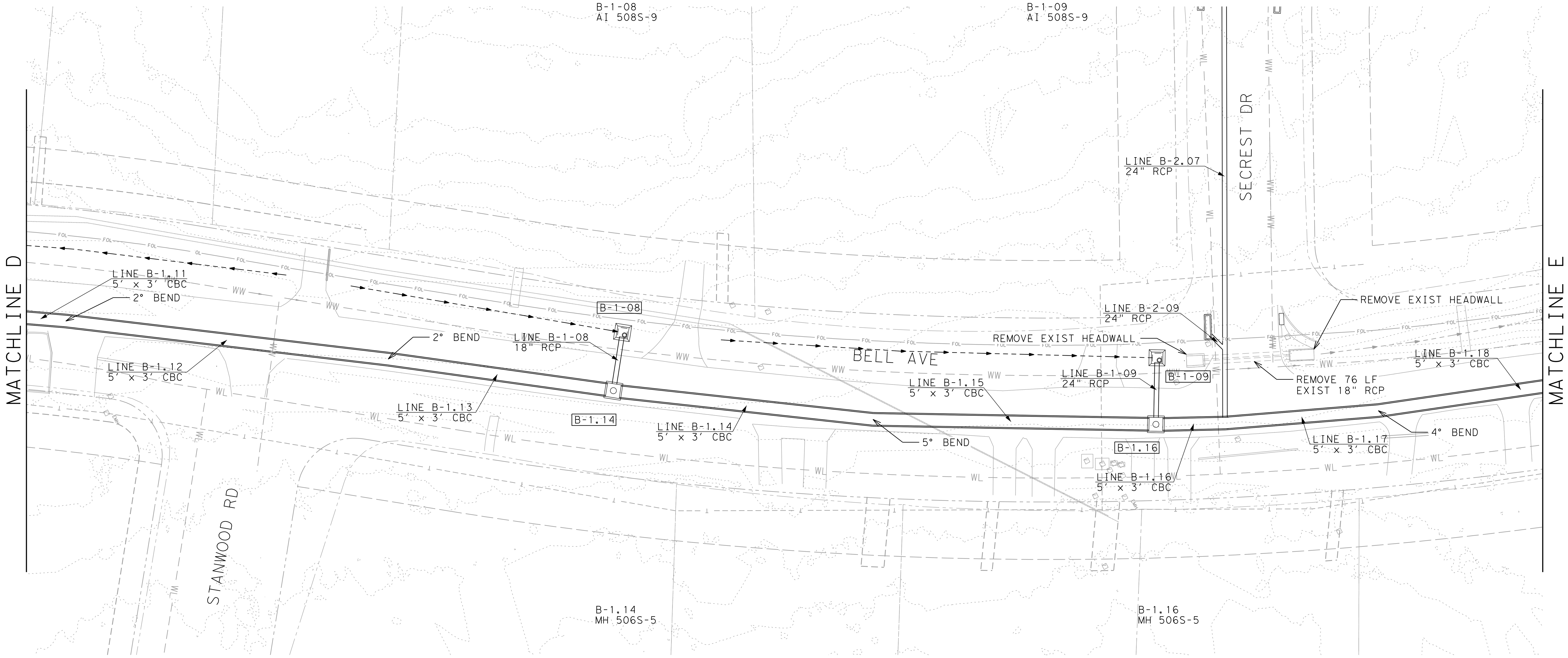
LEGEND
PROPOSED PIPELINE
ROW
PROPERTY LINE
EXISTING EASEMENT
EXISTING WATERLINE
EXISTING WASTEWATER LINE
EXISTING GROUND CONTOUR



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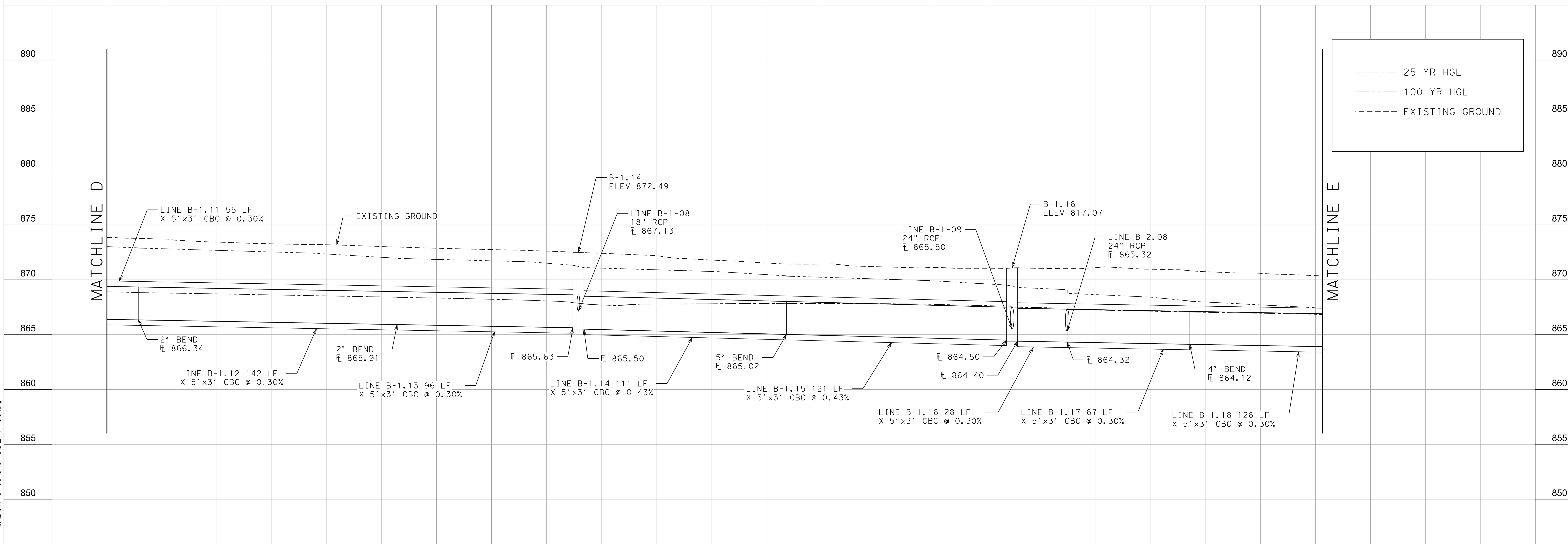

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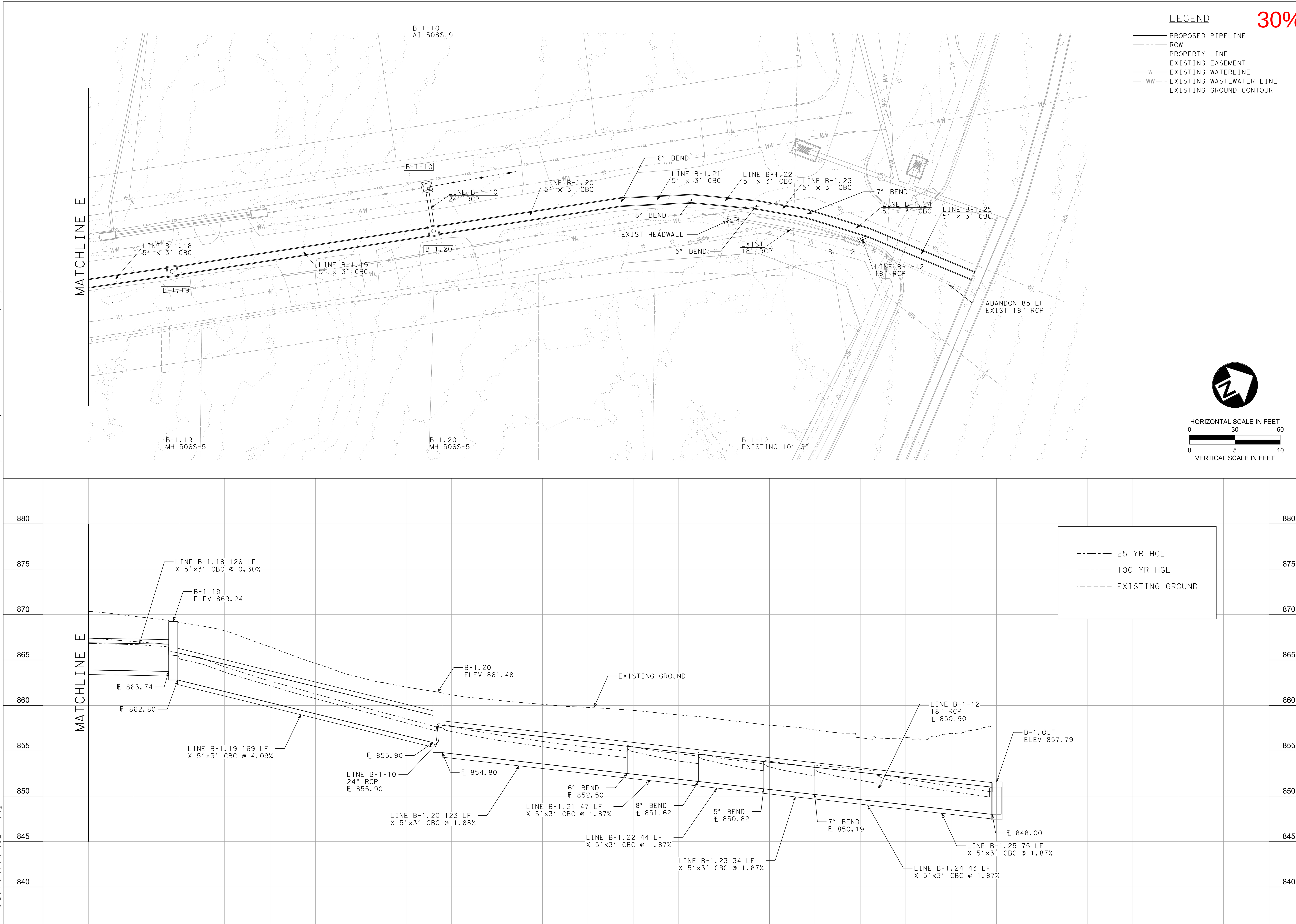

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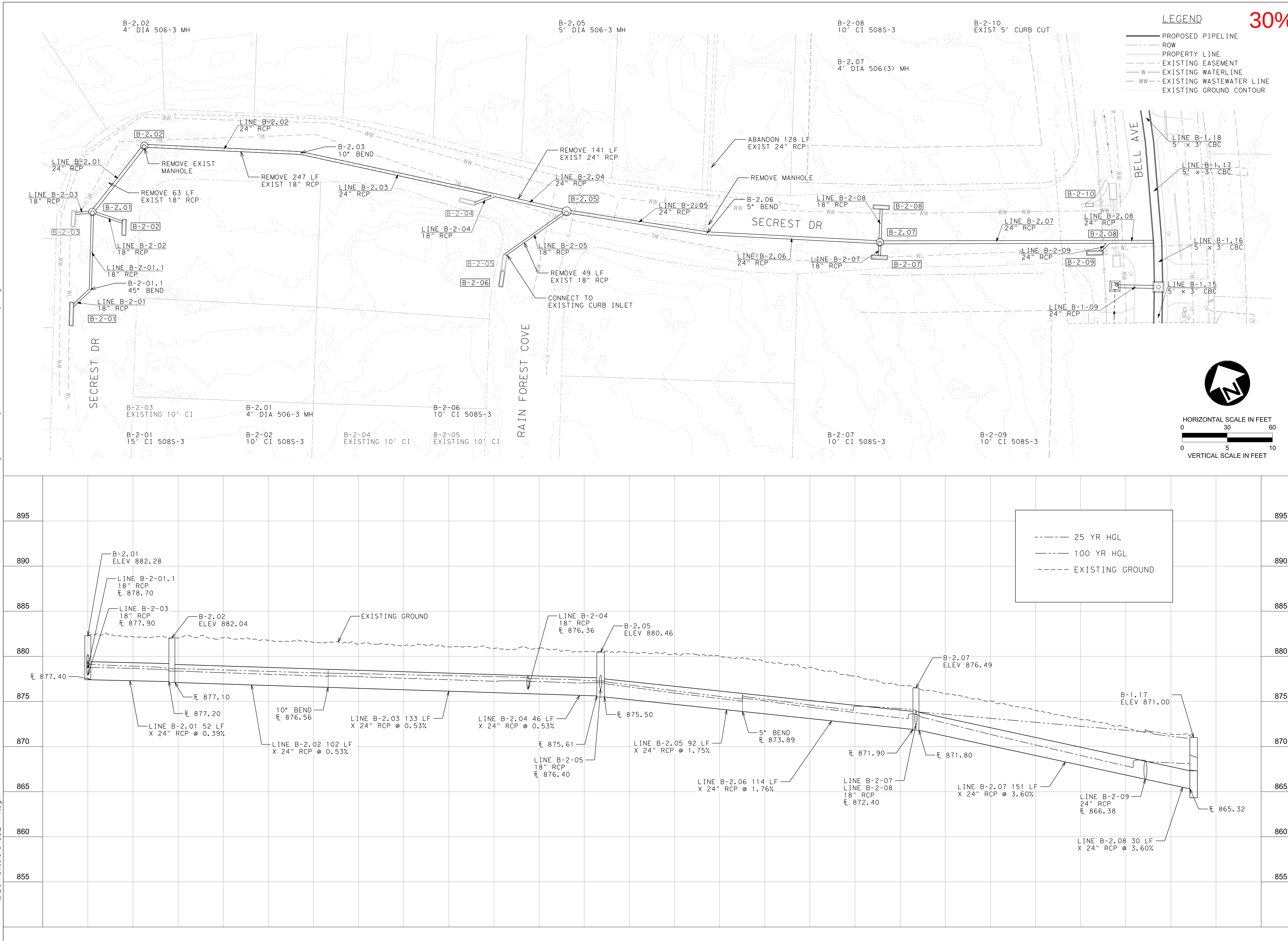

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