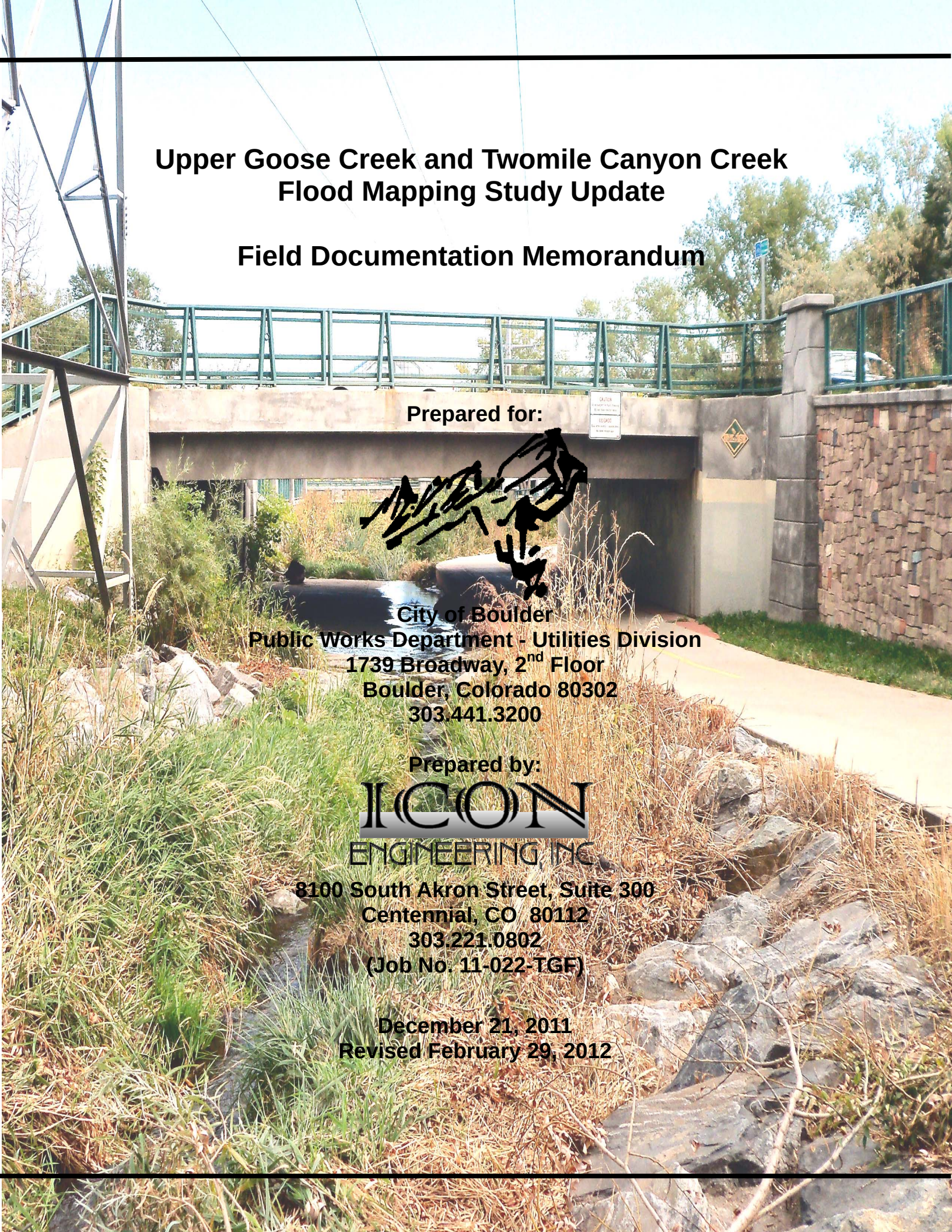

Upper Goose Creek and Twomile Canyon Creek Flood Mapping Study Update

Field Documentation Memorandum

Prepared for:

City of Boulder
Public Works Department - Utilities Division
1739 Broadway, 2nd Floor
Boulder, Colorado 80302
303.441.3200

Prepared by:

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(Job No. 11-022-TGF)

December 21, 2011
Revised February 29, 2012

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Memorandum

TO: City of Boulder, Public Works Department, Utilities Division

FROM: ICON Engineering Inc.

DATE: February 29, 2012

RE: Upper Goose Creek and Twomile Canyon Creek Floodplain Mapping Study Update – Field Documentation Memorandum.

1. Purpose:

The purpose of this memorandum is to provide documentation regarding the field survey and reconnaissance that was completed as part of the Upper Goose Creek and Twomile Canyon Creek Floodplain Mapping Study Update project. This memorandum also provides general recommendations regarding the inclusion of culverts in the hydraulic modeling, expansion and contraction coefficients at culvert and bridge locations, the blockage factor assumptions for each bridge, culvert, and associated railings for each storm frequency, Manning's 'n' values, and recommendations for modeling obstructions in overbank areas.

Given the hydraulic complexity of the drainageways, this Field Documentation Memorandum should be considered as an initial iteration. Either survey or field follow up in other locations may be required based on the results of the floodplain analyses.

2. Project Limits and Reach Descriptions:

The hydraulic modeling for Upper Goose Creek will be completed using the U.S. Army Corps of Engineers (COE) computed program HEC-RAS (Reference 1). The hydraulic analysis will tie-in to the effective information for Goose Creek upstream of Folsom Street and will extend upstream to North Boulder Park. Drainageway sections from Folsom Street to 19th Street reflect open channel conditions with urban development on the northern channel bank and steeper open space terrain along the southern bank. Upstream of 19th Street, to North Boulder Park, low flows are conveyed within conduit systems varying in size from a 24-inch diameter pipe near the park, to a 48-inch pipe near the 19th Street outfall. Floodplain flows will follow ground topography above the conduits, through urban and residential development areas. Conduit capacity will be considered based on other studies previously completed for the City of Boulder. Figure 1 and 2 illustrate the field documentation along Upper Goose Creek.

Hydraulic modeling for Twomile Canyon Creek will tie into Upper Goose Creek at the downstream limits and extend through the City of Boulder's corporate limits at the upstream end, west of Spring Valley Road, near Linden Avenue. To define the complicated split flow conditions at the upper reaches of the study, hydraulic modeling for

Twomile Canyon Creek will be completed using a combination of two hydraulic modeling techniques. Initially, FLO-2D (Reference 2) will be utilized to identify channel and split flow discharges to define conveyance to Upper Goose Creek. At the current time, the boundary requirements of the FLO-2D model are unknown, but at a minimum, the model is expected to encompass the portion of the Twomile Canyon Creek, west of Broadway Street and north of Hawthorne Avenue. For the purposes of this memorandum, this boundary has been used to document the field conditions approach and assumptions for the FLO-2D modeling. Similar applications will be made for other areas where the model is expanded to.

Similarly to the limits of the FLO-2D modeling, the open channel portion of Twomile Canyon Creek exists upstream of Broadway Street, in addition to along Iris Avenue between Broadway and the outfall to the Farmers Ditch. These areas have been the focus of the field documentation at the current time, as it is remains unknown which portion of the discharge (if any) will continue to follow the historic Federal Emergency Management Agency (FEMA) floodplain path southeast of the Broadway/Iris intersection. For the documentation reaches the Twomile Canyon Creek channel is small, and densely vegetated. Private access bridges cross the channel at several locations. Many of these bridges have limited structural integrity and are questionable to withstand major storm events. Overbank areas within this reach generally consist of large lot residential development dense vegetation and fence lines throughout.

At the current time, only a limited field work has been completed, east of Broadway until further information is determined regarding the flood hazards; however flooding in this area is anticipated to be urban in nature, through neighborhood and roadway areas. Figure 3 illustrates the field documentation along Twomile Canyon Creek.

3. Field Survey:

Field survey was completed for the project reaches described above in October 2011 by ICON/Aspen Joint Venture. Field survey references the Colorado State Plane NAD 83 HARN North Zone horizontal control and the North American Vertical Datum (NAVD) of 1988 vertical control. In general, surveyed cross-sections were taken at approximately 300-foot intervals to collect invert and grade brake elevations, tied back into the 1-foot contour base mapping. Supplemental channel invert elevations were also collected at approximately 50-foot intervals between cross-sections to verify channel inverts and grade changes. Survey was collected at existing bridges and culvert crossings larger than 24” in diameter. Channel cross-sections were surveyed upstream and downstream of the crossings, and elevations were collected for the structural elevations. Field sketches for each bridge structure have also been collected. This information has been included in Appendix A of this report.

4. Manning’s ‘n’ Value Selection & Obstruction Modeling Approach:

Based on the field reconnaissance, Manning ‘n’ values for channel roughness have been recommended for the varying channel and overbank conditions to be used in both the FLO-2D and HEC-RAS modeling. Manning’s ‘n’ selection was compiled for the channel section, the channel overbanks, as well as the floodplain overbank areas beyond the photograph limits. The channel section and the immediate channel overbank Manning’s n values have been estimated based on field reconnaissance photographs using

recommendations from the *Open-Channel Hydraulics (*Reference 3*)*. Photographic correlation can be found in Appendix B. Floodplain overbank Manning's n values have been estimated based on aerial imaging and typical land use properties. Recommended low flow channel Manning's n values are summarized below in Table 1.

Table 1 – Channel Manning's 'n' Value Recommendations

Typical Channel Description	Manning's 'n' Value	Chow Designation[1]
Channel		
concrete	0.015	B-2, c, 2
clean, winding, some pools and shoals, short/medium height grass	0.04	D-1, a, 3
clean, winding, some pools and shoals, short/medium height grass, and stones/cobbles	0.05	D-1, a, 6
clean, winding, some pools and shoals, medium/tall height grass, and boulders	0.06	D-1, a, 6 (w/ boulders)
medium/tall height grass, light to medium density trees	0.08	D-1, a, 7/8

[1]See Table 5-6 from Chow's *Open-Channel Hydraulics* (excerpt included in Appendix B)

The main channel overbank areas along Twomile Creek generally consist of dense vegetation and residential landscaping with fences near the main channel and low to medium density residential development with pockets of open space and agricultural land east of Broadway Street throughout the floodplain overbanks. The main channel overbank areas along Upper Goose Creek also generally consist of dense tree vegetation and residential landscaping with fences. The floodplain overbank areas for Upper Goose Creek are also quite varied between dense urban development corridors, extending from North Boulder Park through Broadway Street, medium to high density residential development along Alpine Avenue to 19th Street, and a combination of open space terrain and low density residential development from 19th Street to Folsom Street. For the HEC-RAS modeling, modeling of these areas will generally follow the guidance set forth in *Open-Channel* Hydraulics, as applicable to urban settings. Recommended 'n' values for all overbank conditions are presented in Table 2.

Table 2 – Overbank Manning's 'n' Value Recommendations (HEC-RAS)

Typical Channel Description	Manning's 'n' Value	Chow Designation[1]
Overbank		
concrete / asphalt pavement	0.015	B-2, c, 2 / B-2, i, 1-2
short/medium height grass, no trees	0.04	D-2, a, 1
medium/tall height grass and brush, no trees	0.05	D-2, c, 1
medium/tall height grass, sparse trees	0.06	D-2, c, 3
medium/tall height grass, light to medium density trees	0.08	D-2, d, 3/4
tall grass, medium to high density trees	0.09	D-2, d, 3/4
tall grass, some underbrush, high density trees	0.10	D-2, d, 4
high density vegetation or typical residential landscaping with fences	0.13	D-2, d, 4 (w/ fences)

[1]See Table 5-6 from Chow's *Open-Channel Hydraulics* (excerpt included in Appendix B)

For use in the FLO-2D model, roughness factors for the channel and overbanks will follow the guidance described above. For floodplain overbank areas, including roadway conveyance areas, Manning's 'n' values will be derived from recommendations provided by the FLO-2D manual (Reference 2). Applicable FLO-2D roughness coefficients are presented in Table 3. Figure 4 presents the initial FLO-2D boundary depicting the overbank roughness values proposed for the FLO-2D modeling.

Table 3 – Overbank Manning's 'n' Value Recommendations (Flo-2D)

Typical Floodplain Description	Manning's 'n' Value
concrete / asphalt pavement	0.03
open field	0.15
business / light industrial	0.10
single family residential with typical landscape and fencing	0.40
channel	see Table 1

Upon selection of the Manning's 'n' values, a comparison was made to that of the effective information, specifically the 2002 Flood Insurance Study (FIS) information (Reference 4) and the 1987 Flood Hazard Area Delineation (Reference 5). In general, the Manning's 'n' values used by the FIS/FHAD study along Twomile Canyon Creek ranged from 0.025 to 0.20 in the channel areas and from 0.05 to 0.13 in the overbank areas, thus comparing well with those proposed for the update. Similarly, for urban areas along Upper Goose Creek, Manning's 'n' values ranged from 0.025 to 0.04 in the channel areas and from 0.05 to 0.07 in the overbank areas. For the open channel reaches of Upper Goose Creek, the 'n' values ranged from 0.02 to 0.13 in the channel areas and from 0.05 to 0.13 in the overbank areas, again comparing well with the recommended values.

Upon review of the channel and floodplain areas, it is proposed that for this study buildings located within the floodplain areas be modeled utilizing the blocked obstruction routines in HEC-RAS. Similarly, for FLO-2D it is proposed that conveyance be reduced by area-reduction-factors (ARFs) based on the building footprints presented in the City's GIS database. We believe that this will more accurately reflect field conditions as opposed to a bare earth analysis. The presence of fences will not be modeled as obstructions, but considered in the selection of the Manning's 'n' values.

5. Bridges and Culverts

Bridges and culverts identified in Table 4 have been evaluated and surveyed for inclusion in the hydraulic modeling. As previously discussed, at the direction of the City, culverts 24-inches and smaller in diameter were not included in the survey and will not be modeled in the hydraulic analysis. Similarly, non-anchored plank type social bridges were not included in the survey and will not be modeled in the hydraulic analysis. Social bridges that appeared well constructed but that are not securely anchored to abutments will be included in the hydraulic model as lids at individual cross sections. This approach to the hydraulic analysis will account for the reduction in channel area that is blocked by the bridge structure, but without the use of a full bridge modeling routine. This approach has also been chosen given the high potential for these structures to become dislodged during high discharge events.

Bridges and culverts are documented by project field points, field notes and photographs included in Appendix A. The bridges and culverts located in the field are summarized in Table 4, along with recommended contraction and expansion coefficients, and blockage considerations for each storm frequency. Several of the bridges are noted as 'n/a' in the table. For these structures, it is recommended that they not be included in the modeling based on the appearance of their general structural integrity.

As discussed above, a storm sewer network is located along Upper Goose Creek between North Boulder Park and 19th Street. At the current time, the capacity of this system has not been evaluated; however given the large number of laterals and inlets draining to the system, in addition to the new collection system on Broadway Street, the potential that the system will function at, or near, it's maximum capacity is high during major storm events. Therefore, it is recommended to only apply a 10% reduction factor on the system's design capacity.

6. Contraction and Expansion Coefficients

Contraction and expansion coefficients for the bridges and culverts included in the hydraulic model have been set based on information presented in the HEC-RAS user's manual. Typically, bridge sections will have contraction and expansion coefficients of 0.3 and 0.5 respectively. The social bridges that will be modeled as lids structures will retain the typical channel expansion and contraction coefficients of 0.1 and 0.3 respectively. Culverts included in the hydraulic analysis will utilize contraction and expansion coefficients of 0.6 and 0.8 respectively.

7. Debris Blockage

Recommended debris blockage as a percentage of the total bridge or culvert conveyance area is summarized in Table 4. Please note that the conveyance area provided in Table 4 is only approximate values used for general crossing size classification. The hydraulic model will ultimately provide conveyance area values for each crossing location. The recommended debris blockage values have been estimated based on the size of the bridge or culvert opening and the general presence of vegetation and other debris upstream of the crossing that has potential to block the conveyance area during major storm events. Small crossings generally have opening sizes of 10 square feet or less, medium sized crossings are 10-30 square feet, and large openings are greater than 30 square feet. The drainage area and channels adjacent to all stream crossings include heavy debris loads consisting of natural vegetation and typical residential debris that are likely to cause stream crossing blockage during significant flow events.

This approach is similar to the 1987 FHAD that utilized 100% debris blockage at all culverts along Twomile Canyon Creek. Varying values for the debris blockage for the modeled return intervals have been included to reflect the greater potential for blockage during higher discharge events.

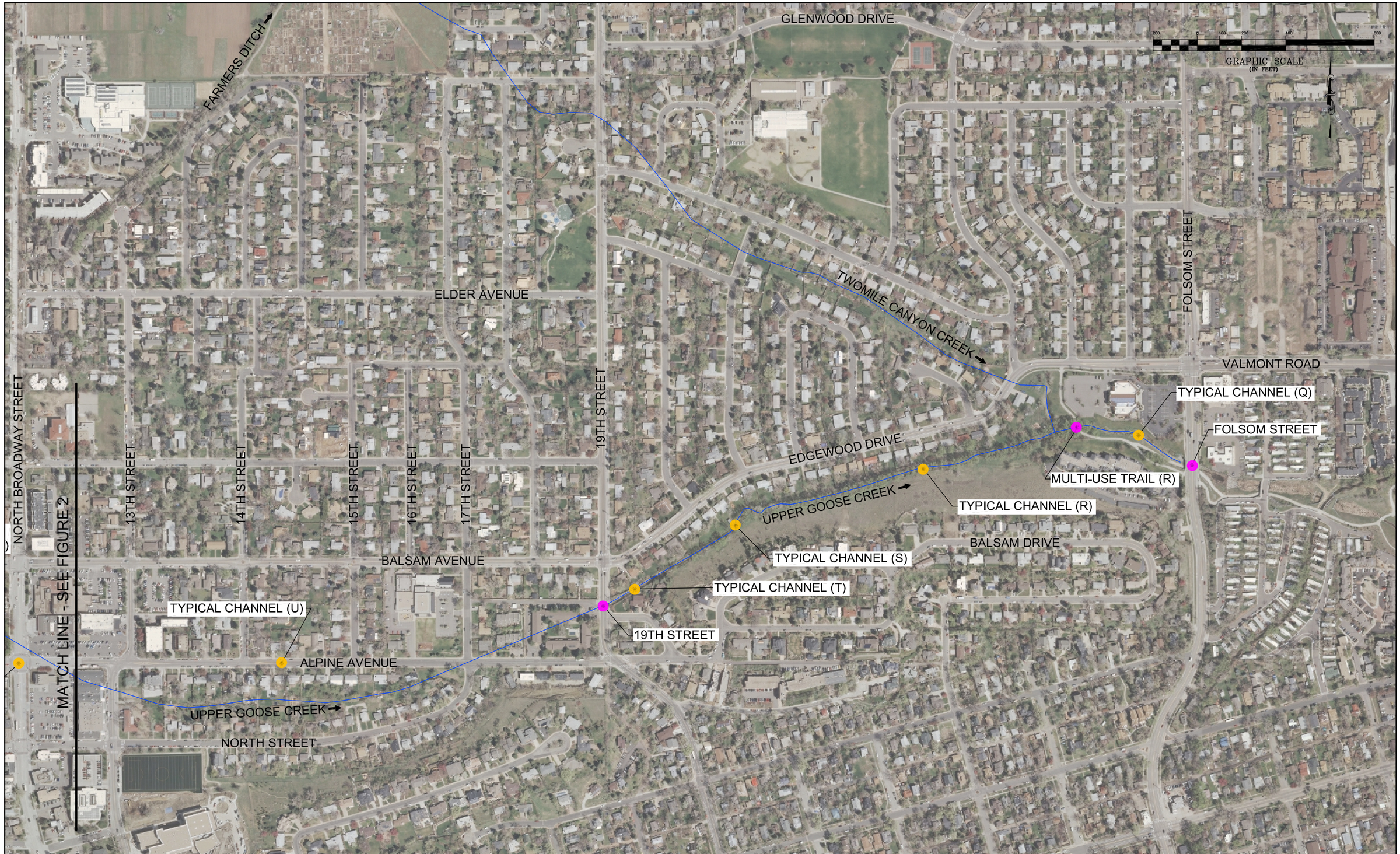
Table 4 also includes bridge and culvert railing obstruction values and documentation. Railings that have significant conveyance capacity and minimal clogging potential will not be modeled (i.e. 0% obstruction). Railings that have minimal conveyance capacity and high clogging potential will be modeled as a complete (100%) obstruction.

8. References

1. *River Analysis System (HEC-RAS),* U.S. Army Corps of Engineers Hydrologic Engineering Center, version 4.1.0, January 2010.
2. *Flo-2D,* Flo-2D Software Inc., version 2009.06.
3. *Open-Channel Hydraulics,* Ven Te Chow, 1988.
4. *Flood Insurance Study, Boulder County, Colorado and Incorporated Areas,* Federal Emergency Management Agency, October 4, 2002.
5. *Flood Hazard Area Delineation, Boulder and Adjacent County Drainageways,* Urban Drainage and Flood Control District, May 1987.

Table 4 - Upper Goose Creek and Twomile Canyon Creek Flood Mapping Study - Channel Crossing Summary

	Channel Crossing				Critical Elevations			Inclusion in Hydraulic Models		HEC-RAS Coefficients		Recommended Debris Blockage							
Channel	**Name**	**Type**	**Culvert / Bridge Size**	**Approximate Hydraulic Area**	**Invert In**	**Crest**	**Invert Out**	**2D (FLO-2D)**	**1D (HEC-RAS)**	**Contraction**	**Expansion**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**500-yr**	**Debris Blockage Reasoning**	**Recommended Railing Debris Blockage Approach**
Twomile Canyon Creek	Private Crossing (Q)	wood bridge	2" thick, 3' wide; 7' span, 3' max rise	11 sf	n/a	n/a	n/a	No	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Private Crossing (P)	wood bridge	6" thick, 4' wide; 6' span, 2' max rise	6 sf	n/a	n/a	n/a	No	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Spring Valley Road	double CMP culvert	3' wide, 5' high	24 sf (sediment fill)	5599.65 / 5600.25	5605.93	5599.27 / 5598.68	Yes	Yes	0.6	0.8	50%	75%	100%	100%	100%	100%	medium opening, sediment, high debris load	n/a
	Multi-Use Trail (O)	steel truss, wood deck	1.8' thick, 10' wide; 23' span, 3.3-foot max rise	38 sf	5577.40	5581.42	5576.30	No	Yes	0.3	0.5	0%	0%	0%	10%	30%	50%	large opening, high debris load	100% blockage due to potential cloging
	Wonderland Hill Avenue	single CMP culvert	32" high, 54" wide	9 sf	5568.86	5573.32	5566.67	Yes	Yes	0.6	0.8	50%	75%	100%	100%	100%	100%	small opening, high debris load	n/a
	Linden Avenue	double CMP culvert	14" by 36", and 32" by 43"	12 sf	5560.74 / 5561.89	5565.13	5558.71 / 5558.53	Yes	Yes	0.6	0.8	25%	50%	75%	100%	100%	100%	medium opening, high debris load	n/a
	Private Crossing (N)	wood bridge	10" thick, 3' wide; 12' span, 2' max rise	12 sf	n/a	n/a	n/a	No	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Private Crossing (M)	steel truss	4" thick, 3' wide; 16' span, 3.9' max rise	50 sf	5524.08	5528.37	5523.43	No	Yes	0.3	0.5	0%	0%	0%	10%	30%	50%	large opening, high debris load	100% blockage due to potential cloging
	Private Crossing (L)	steel truss	1' thick, 8' wide; 17' span, 4.2' max rise	65 sf	5523.22	5528.12	5522.88	No	Yes	0.3	0.5	0%	0%	0%	10%	30%	50%	large opening, high debris load	n/a
	Kalmia Avenue	single CMP culvert	5.0' wide, 3.0' high	12 sf	5512.93	5517.01	5511.15	Yes	Yes	0.6	0.8	25%	50%	75%	100%	100%	100%	medium opening, high debris load	n/a
	Private Crossing (K)	wood bridge	21' long, 6' wide; 21' span, 5.2' max rise	55 sf	5499.64	5505.75	5499.55	No	Yes	0.3	0.5	0%	0%	0%	10%	30%	50%	large opening, high debris load	0% blockage due to open railing style
	Private Crossing (J)	CMP crossing, wood deck	15" thick, 12" wide; 18' span, 4.3' max rise	40 sf	5496.26	5501.37	5495.94	No	Yes	0.6	0.8	0%	0%	0%	10%	30%	50%	large opening, high debris load	n/a
	Private Crossing (I)	wood bridge	0.55' thick, 3.0' wide; 13' span, 3.5' max rise	45 sf	5495.39	5499.40	5495.34	No	Yes	0.3	0.5	0%	0%	0%	10%	30%	50%	large opening, high debris load	100% blockage due to potential cloging
	Private Crossing (H)	wood bridge	4" thick, 1" wide; 16' span, 3' max rise	25 sf	n/a	n/a	n/a	No	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Juniper Avenue	single CMP culvert	54-inch wide, 36-inch high	12 sf	5488.03	5491.98	5486.49	Yes	Yes	0.6	0.8	25%	50%	75%	100%	100%	100%	medium opening, high debris load	n/a
	Private Crossing (A)	wood bridge	11" thick, 4' wide; 25' span, 3.5' max rise	60 sf	n/a	n/a	n/a	No	Yes (lid)	0.1	0.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Private Crossing (B)	wood bridge	10" thick, 3' wide; 22' span, 3' max rise	33 sf	5478.63	5482.46	5478.63	No	Yes (lid)	0.1	0.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Private Crossing (C)	wood bridge	12" thick, 4' wide; 25' span, 5.5' max rise	69 sf	5464.94	5471.54	5464.94	No	Yes (lid)	0.1	0.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0% blockage due to open railing style
	Private Crossing (D)	wood bridge	12" thick, 4' wide; 16' span, 1.7' max rise	14 sf	5463.05	5465.68	5462.77	No	Yes (lid)	0.1	0.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Private Crossing (E, E')	wood bridge	8" thick, 4' wide; 18' span, 2.6' max rise	23 sf	5452.01	5455.20	5451.96	No	Yes (lid)	0.1	0.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Private Crossing (F)	wood bridge	8" thick, 3' wide; 12' span, 2.4' max rise	14 sf	5451.26	5453.55	5450.91	No	Yes (lid)	0.1	0.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Multi-Use Trail (G)	steel truss, concrete deck	7" thick deck, 11' wide; 70' span, 4.7' max rise	66 sf (skew)	5450.00	5454.35	5449.04	No	Yes	0.3	0.5	0%	0%	0%	10%	30%	50%	large opening, high debris load	100% blockage due to potential cloging
	North Broadway Street	single RCP culvert	28" by 44", trans. to 36"	7 sf	5438.33	5446.99	5421.62	Yes	No	n/a	n/a	50%	75%	100%	100%	100%	100%	small opening, high debris load	n/a
	16th Street	single RCP culvert	4' wide, 3' high	9 sf	5406.93	5411.25	--	No	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Upper Goose Creek	9th Street to Broadway	storm sewer system	24" to 36" pipe	3 sf - 7 sf	n/a	n/a	n/a	--	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Broadway to 19th Street	storm sewer system	36" to 54" pipe	7 sf - 16 sf	n/a	n/a	n/a	--	No	n/a	n/a	10%	10%	10%	10%	10%	10%	inlet capacity at Broadway, minimal blockage	n/a
	Multi-Use Trail (R)	concrete bridge	1.4' thick, 16' wide; 20' span, 2.6' max rise	52 sf	5308.68	5312.60	5308.55	--	Yes	0.3	0.5	0%	0%	0%	10%	30%	50%	large opening, high debris load	n/a



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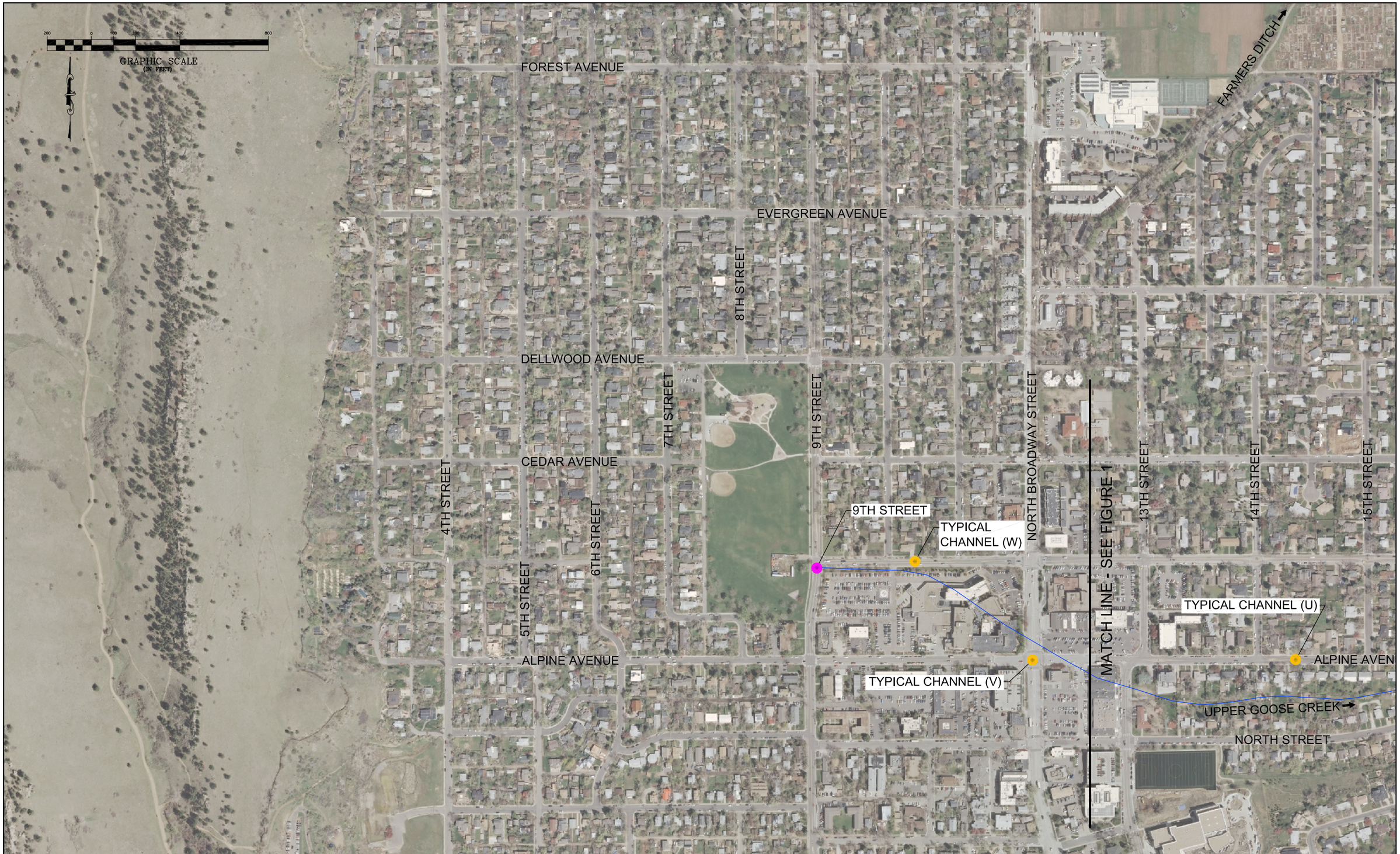
UPPER GOOSE CREEK AND TWOMILE CANYON CREEK
FLOOD MAPPING STUDY UPDATE

FIELD DOCUMENTATION MAP
UPPER GOOSE CREEK

DATE
DEC 2011

FIGURE
1



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UPPER GOOSE CREEK AND TWOMILE CANYON CREEK
FLOOD MAPPING STUDY UPDATE

FIELD DOCUMENTATION MAP
UPPER GOOSE CREEK

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FIGURE
2

No.	DATE	REVISIONS	APPR.

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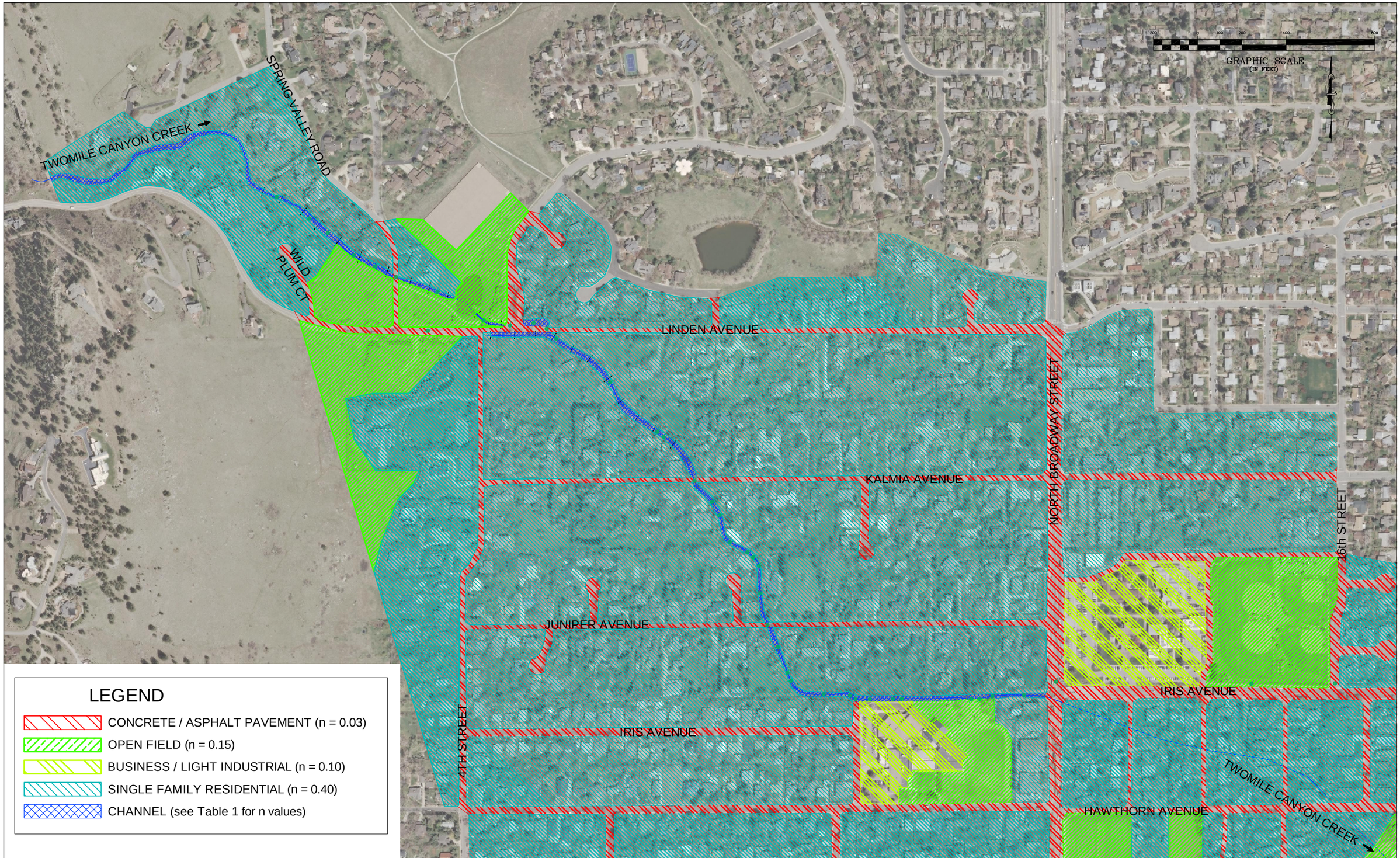
UPPER GOOSE CREEK AND TWOMILE CANYON CREEK
FLOOD MAPPING STUDY UPDATE

FIELD DOCUMENTATION MAP
TWOMILE CANYON CREEK

DATE
DEC 2011

FIGURE
3



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UPPER GOOSE CREEK AND TWOMILE CANYON CREEK
FLOOD MAPPING STUDY UPDATE

FLO-2D OVERBANK MANNING'S N VALUES
TWOMILE CANYON CREEK

DATE
DEC 2011

FIGURE
4

Appendix A
Field Survey
(crossing structures)

Looking upstream at multi-use crossing

Looking northwest at multi-use crossing

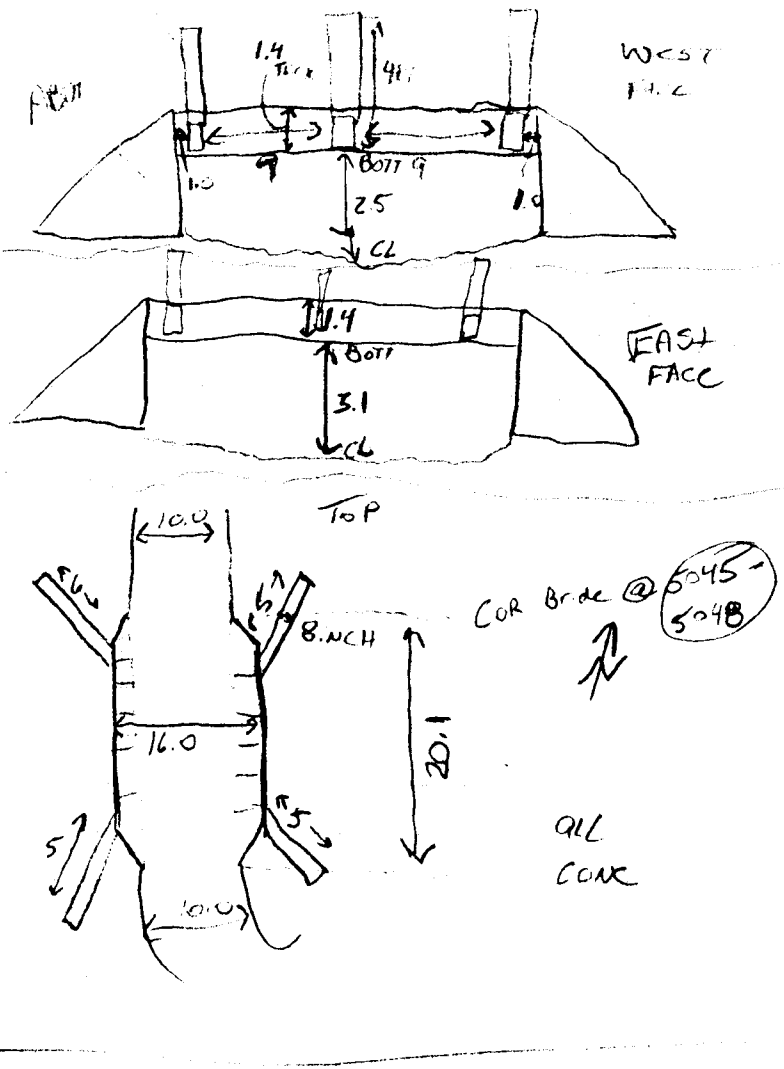
Bridge Width = 16.0 Feet

Bridge Crest
Elevation=5312.60

Looking downstream at multi-use crossing

Invert In = 5308.68

Looking at downstream face of multi-use crossing


WEST FACE
1.4
4.1
BOTT
2.5
CL
1.0
EAST FACE
1.4
BOTT
3.1
CL
TOP
10.0
8.INCH
16.0
20.1
10.0
COR Bridge @ 5045 - 5048
ALL CONC

NEXT CP 5073

Top of 48" RCP = 5340.97

Looking upstream at 19th Street culvert outfall

Top of 48" RCP = 5340.96

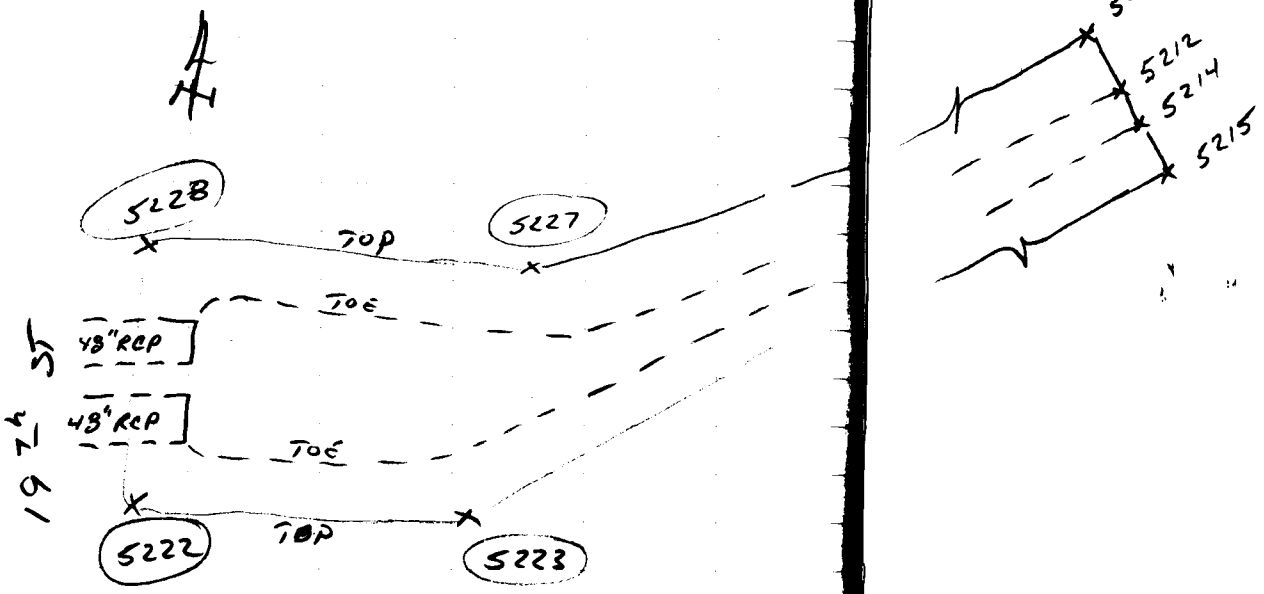
Concrete Toe Elevation = 5337.29

19th Street culvert outfall

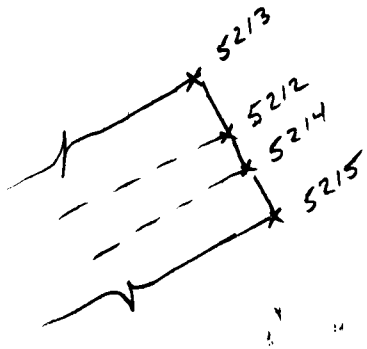
Concrete Toe Elevation = 5337.58

Goose Creek At 19th Street

GOOSE / BOULDER



Goose Creek channel



GOOSE CREEK AT 19TH STREET

Looking at inlet grate upstream of 9th Street

Looking east at inlet on west side of park

Looking upstream at Folsom Street bridge

RAIL HEIGHT = 4.0 FT

Looking upstream at Folsom Street bridge

BRIDGE THICKNESS = 4.3 FT

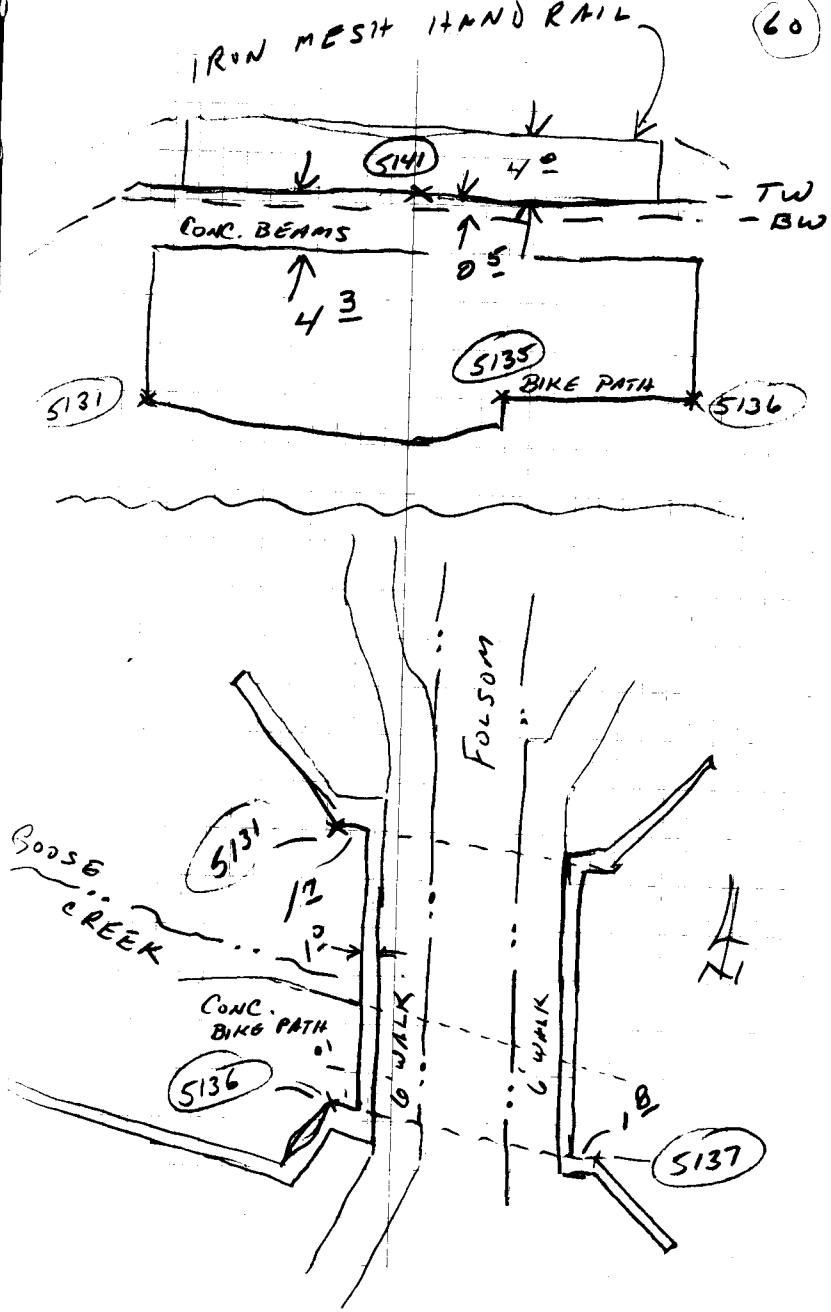
Looking upstream at Folsom Street bridge

Looking downstream at Folsom Street bridge

INVERT IN = 5299.24

Looking downstream at Folsom Street bridge and drop structure

BOULDER/GOOSE 10/25/11



GOOSE CREEK AT FOLSOM

Looking downstream at pedestrian bridge

THICKNESS = 10 3/4 INCHES

Looking downstream at pedestrian bridge

DECK THICKNESS = 10 INCHES

INVERT IN, OUT = 5478.63

Looking northeast at pedestrian bridge

CREST ELEVATION = 5482.46

PRIVATE CROSSING (B) - Twomile Canyon Creek

BRIDGE THICKNESS = 12 INCHES

Looking downstream at private crossing

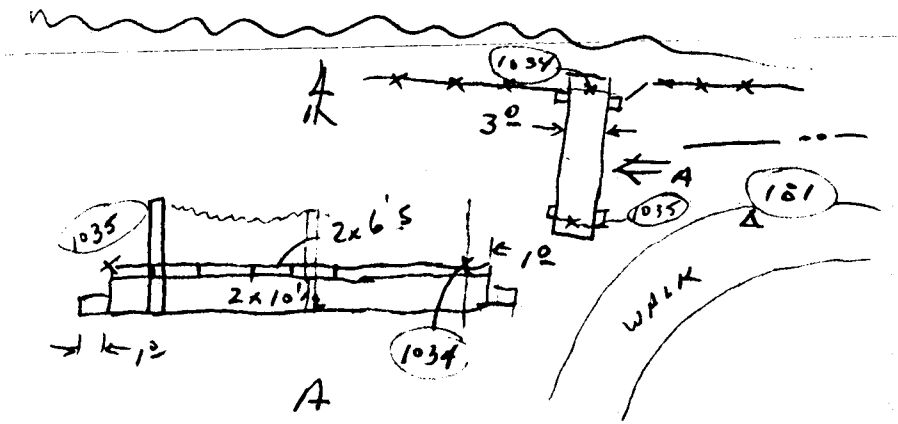
INVERT IN = 5464.94

Looking upstream at private crossing

BRIDGE CREST ELEVATION = 5471.47

INVERT IN = 5464.94

PRIVATE CROSSING (C) - Twomile Canyon Creek



PRIVATE CROSSING (C) - Twomile Canyon Creek

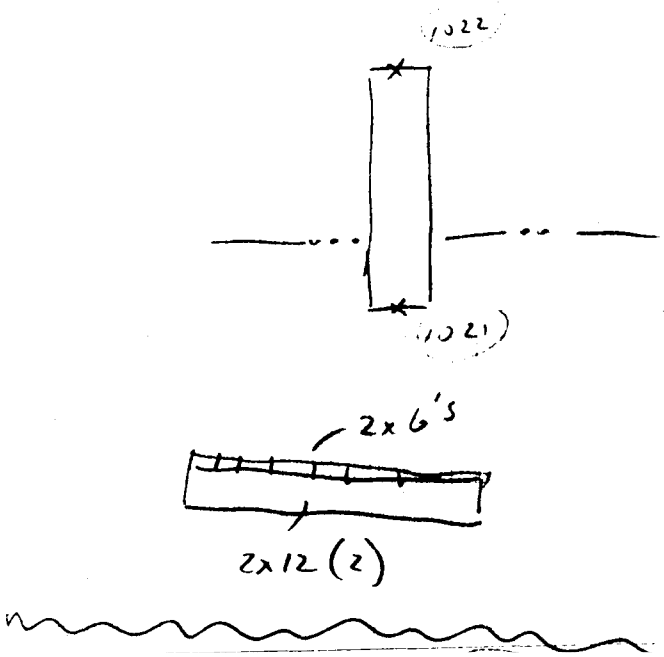
BRIDGE CREST
ELEVATION = 5465.68

Looking downstream at private crossing

INVERT IN = 5463.05
INVERT OUT = 5462.77

BRIDGE THICKNESS =
14 INCHES

PRIVATE CROSSING (D) - Twomile Canyon Creek


1022
1021
2x6's
2x12 (2)

Looking upstream at private crossing

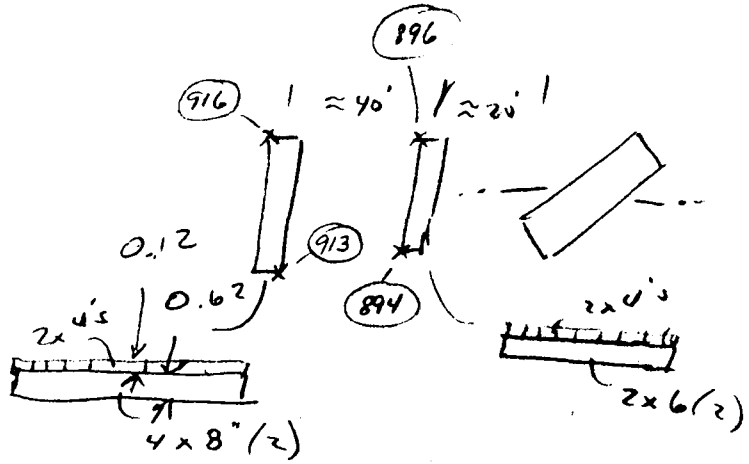
BRIDGE THICKNESS =
14 INCHES

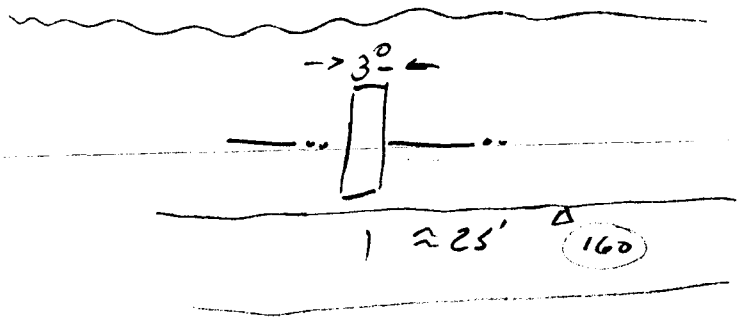
Looking upstream from private crossing

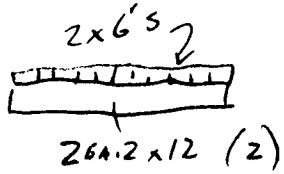
Looking upstream at private crossing

PRIVATE CROSSINGS (E, E' & F) - Twomile Canyon Creek

Looking upstream at private crossing


896
916
≈ 40'
≈ 20'
0.12
913
0.62
894
2x4's
2x4's
4x8" (2)
2x6 (2)


3°
≈ 25'
160


2x6's
26A.2 x 12 (2)

Looking downstream at multi-use trail crossing

Looking downstream at multi-use trail crossing

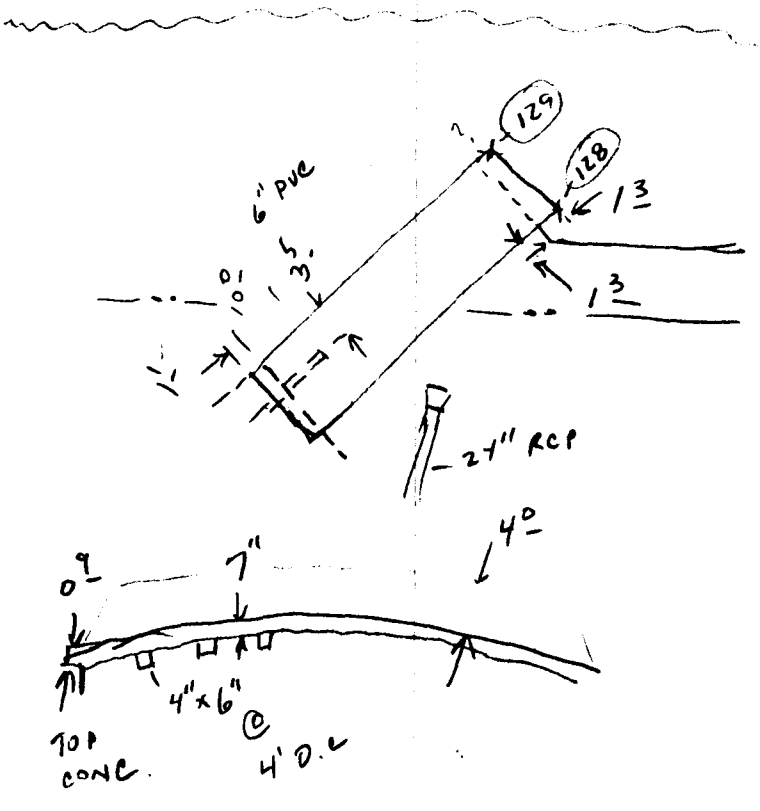
INVERT IN = 5450.00

MULTI-USE TRAIL (G) - Twomile Canyon Creek

Looking upstream at multi-use trail crossing

BRIDGE CREST ELEVATION = 5454.35

Looking upstream at multi-use trail crossing


129
128
6" PVC
1 3
1 3
24" RCP
4°
0°
7"
4"x6" @ 4' O.C
TOP CONC.

Looking upstream at private crossing

Looking upstream at private crossing

BRIDGE CREST = 5499.4

Looking upstream at private crossing

RAIL HEIGHT = 1.3 FEET

DECK THICKNESS = 0.55 FOOT

PRIVATE CROSSING (I) - Twomile Canyon Creek

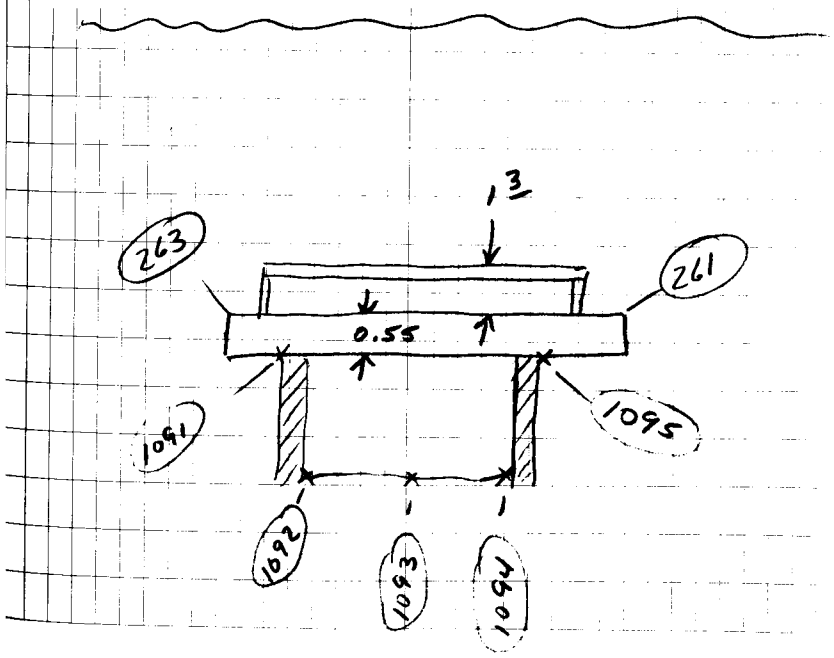
Looking southwest at private crossing

INVERT OUT = 5495.34

INVERT IN = 5495.39

PRIVATE CROSSING (I) - Twomile Canyon Creek

Goose / Boulder 11/07/11



Looking west at private crossing

BRIDGE CREST = 5501.37

Looking west at private crossing

INVERT IN = 5496.26

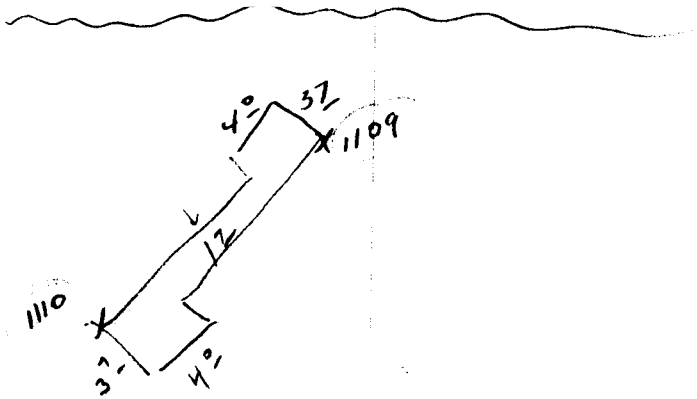
PRIVATE CROSSING (J) - Twomile Canyon Creek

Looking upstream at private crossing

INVERT OUT = 5495.94

FLUME THICKNESS = 13.5 INCHES

PRIVATE CROSSING (J) - Twomile Canyon Creek



Private Crossing (J) - Twomile Canyon Creek

RAIL HEIGHT = 3 FEET

Looking upstream at private crossing

DECK THICKNESS = 15 INCHES

INVERT OUT = 5499.55

PRIVATE CROSSING (K) - Twomile Canyon Creek

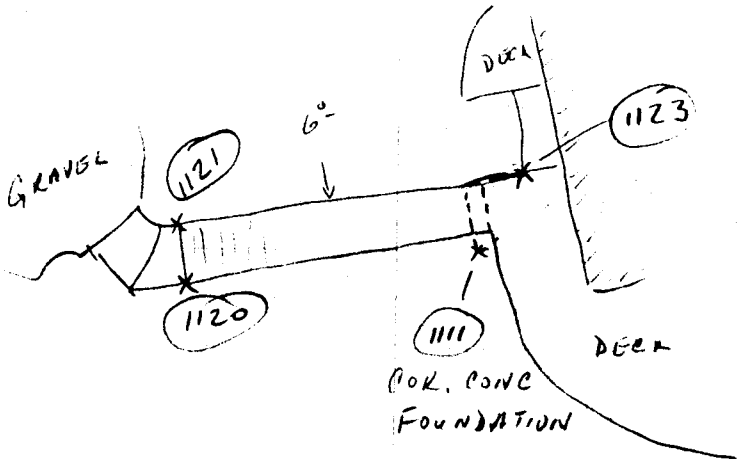
CREST ELEVATION = 5505.75

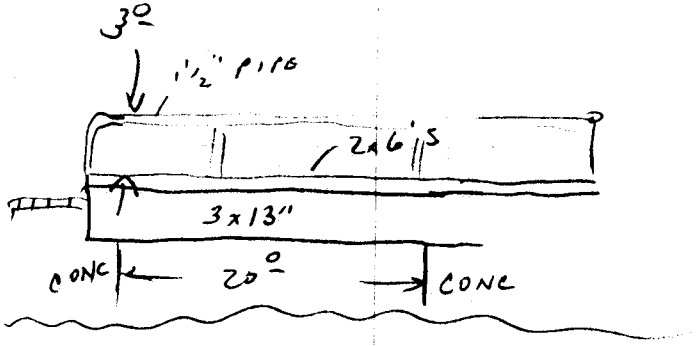
Right abutment of private crossing

INVERT IN = 5499.64

PRIVATE CROSSING (K) - Twomile Canyon Creek

Left abutment of private crossing


DECK
6"
1123
GRAVEL
1121
1120
1111
DECK
POR. CONC
FOUNDATION


3"
1½" PIPE
2x6's
3x13"
CONC
20"
CONC

DECK THICKNESS = 1 FOOT

BRIDGE CREST = 5528.12

Looking upstream at private crossing

INVERT OUT = 5522.88

INVERT IN = 5523.22

Looking upstream at private crossing

RAIL HEIGHT = 31 INCHES

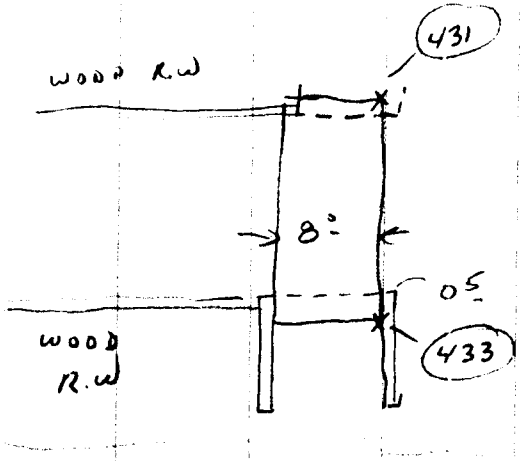
Looking upstream at private crossing

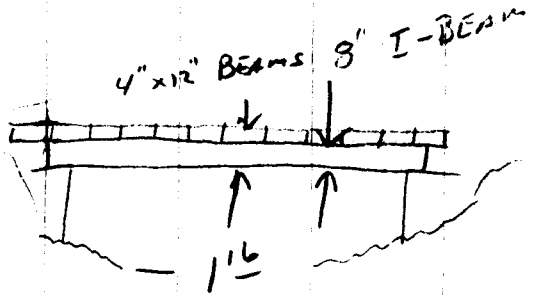
INVERT IN = 5524.08

DECK THICKNESS = 4 INCHES

BRIDGE CREST = 5528.37

Private crossing bridge deck


431
WOOD R.W
8'
0.5
WOOD R.W
433


4"x12" BEAMS
8" I-BEAM
1'6

Looking upstream at private crossing

Looking upstream at private crossing

RAIL HEIGHT = 3.5 FEET

Looking upstream towards multi-use trail bridge

DECK THICKNESS = 1.8 FEET

INVERT OUT = 5576.30

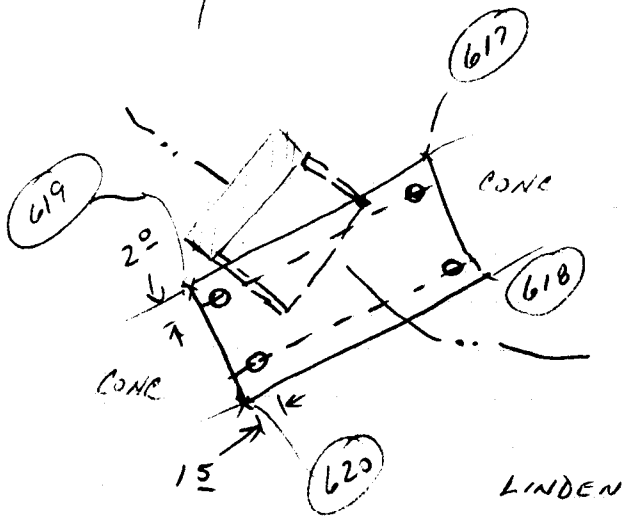
INVERT IN = 5577.40

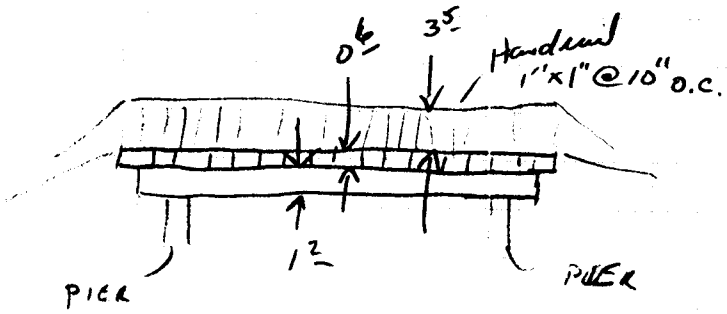
MULTI-USE TRAIL (O) - Twomile Canyon Creek

Looking east towards multi-use trail bridge

BRIDGE CREST = 5581.42

4


617
619
CONC
2°
618
CONC
1 5
620
LINDEN


0 6
3 5
Handrail
1"x1" @ 10" o.c.
1 2
PIER
PIER

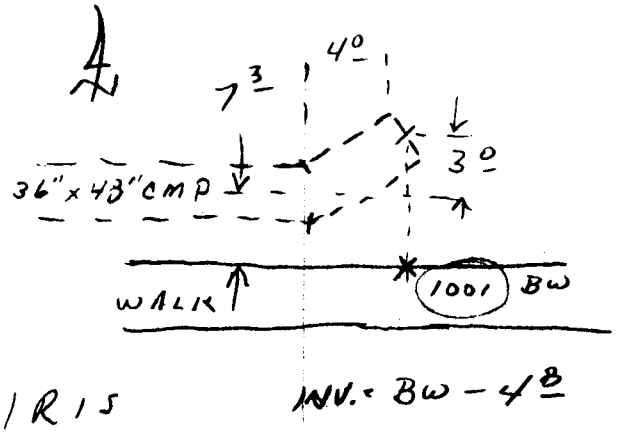
Looking downstream at private crossing

Looking upstream at private crossing

Looking at upstream face of 16th Street culvert

Looking upstream from 16th Street culvert

Farmers Ditch at approximate 16th Street culvert discharge location


4
7.3
4.0
3.0
36"x48" CMP
WALK
1001
BW
IRIS
INV. = BW - 4.8

CL 12" HEADWALL = 5448.04

Upstream face of Broadway / Iris culvert

Upstream face of Broadway / Iris culvert

INVERT IN, 3 FT x 4 FT RCP = 5438.33

Upstream face of Broadway / Iris culvert

Looking east across the Broadway / Iris intersection

NORTH BROADWAY STREET - Twomile Canyon Creek

Downstream face of Broadway culvert

INVERT OUT, 32" RCP = 5421.62

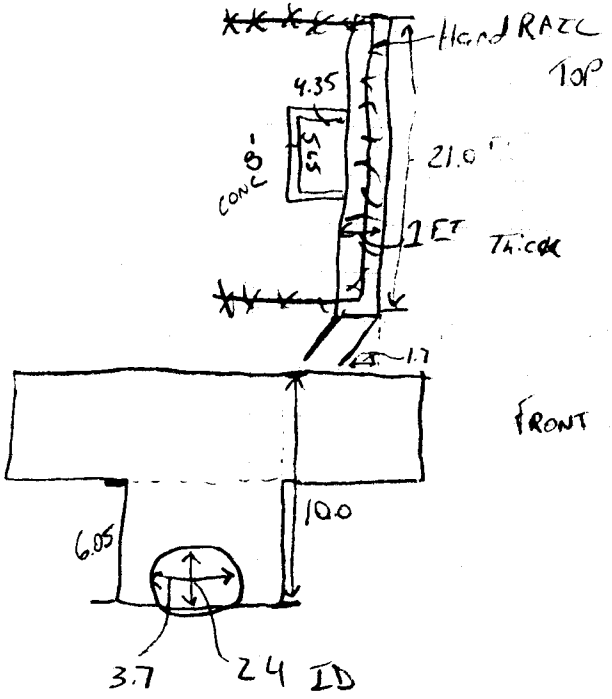
NORTH BROADWAY STREET - Twomile Canyon Creek

Downstream face of Broadway culvert

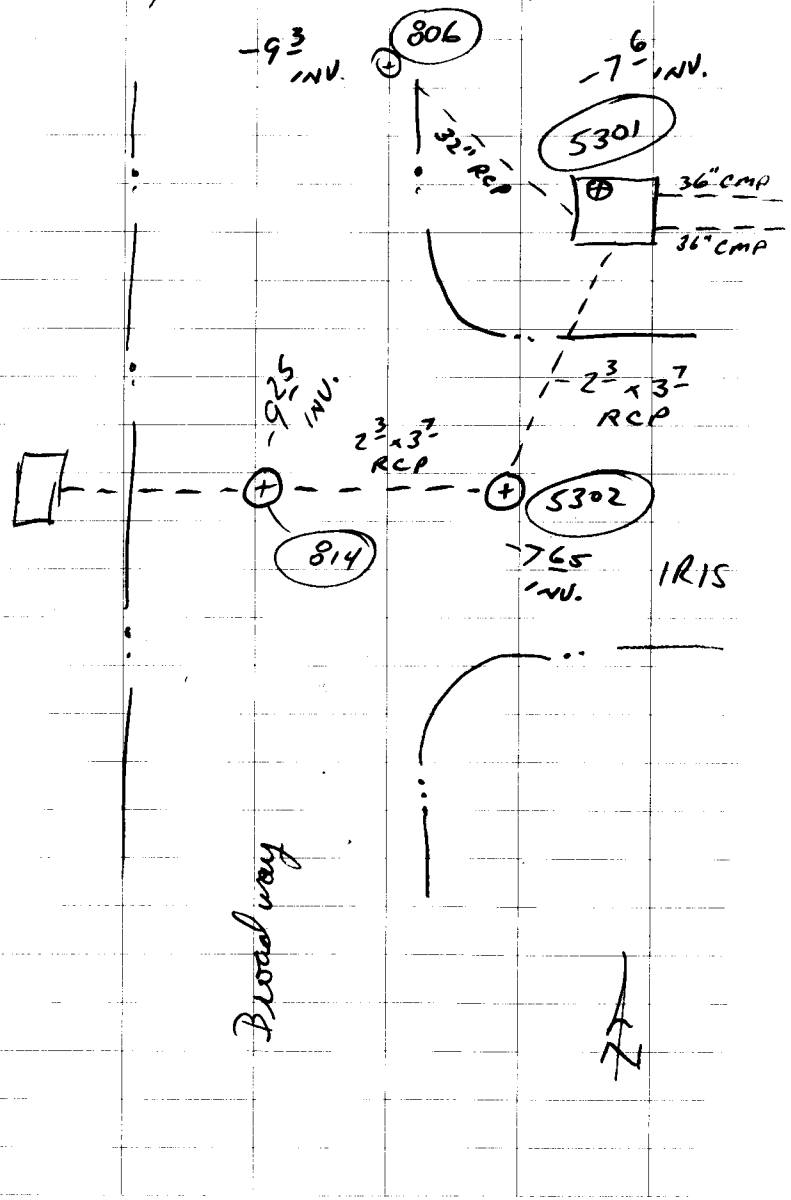
NORTH BROADWAY STREET- Twomile Canyon Creek

IRS and Boundary

24
3.7



Goose / Boulder 11/07/11

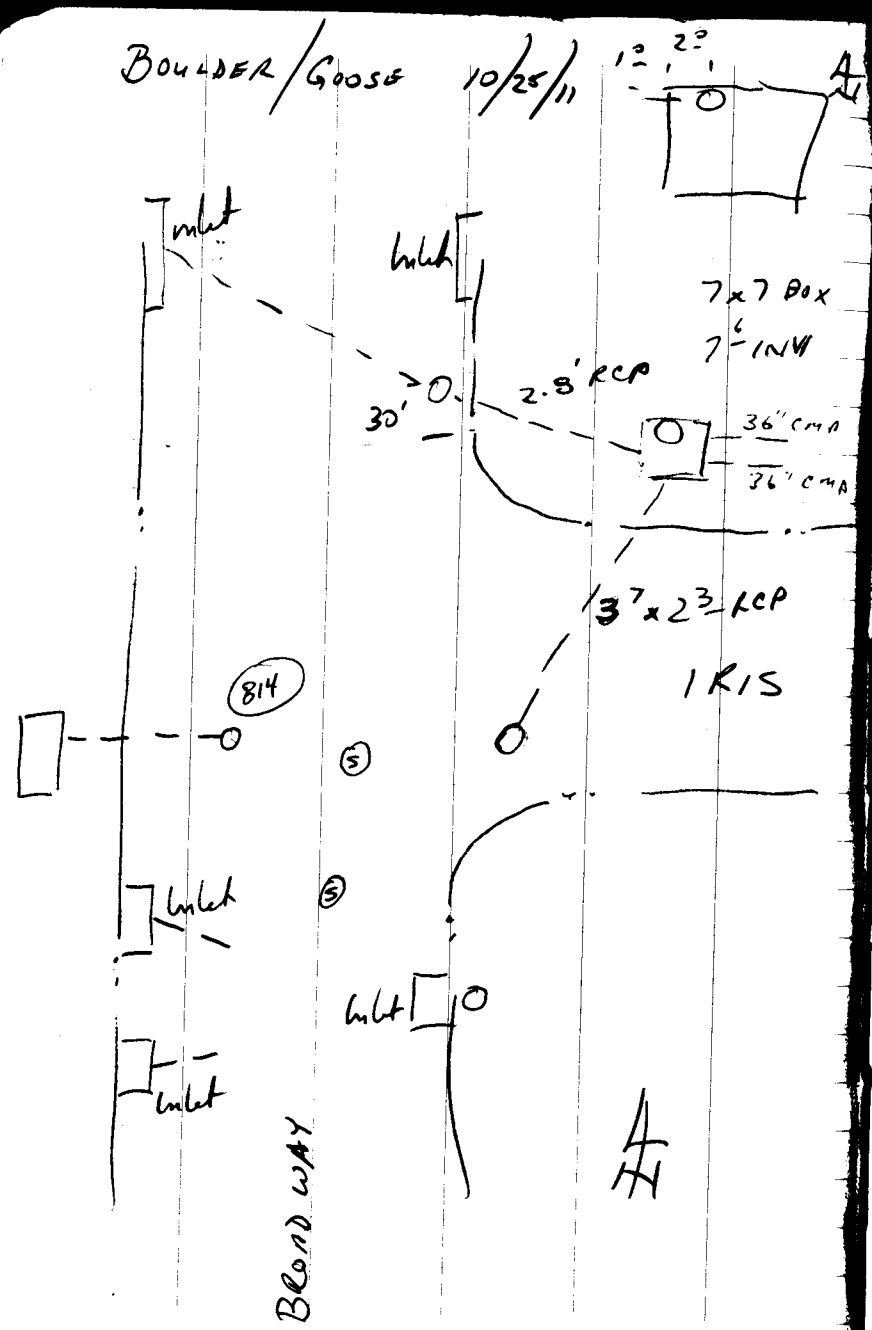


62

SPC

5301 ℄ Rim

5302 ℄ Rim



NORTH BROADWAY STREET - Twomile Canyon Creek

Upstream face of Juniper Avenue culvert

INVERT IN, 36" X 54" CMP = 5488.03

ROADWAY CREST = 5491.98

Upstream face of Juniper Avenue culvert

Looking west along Juniper Avenue near culvert crossing

Looking east along Juniper Avenue near culvert crossing

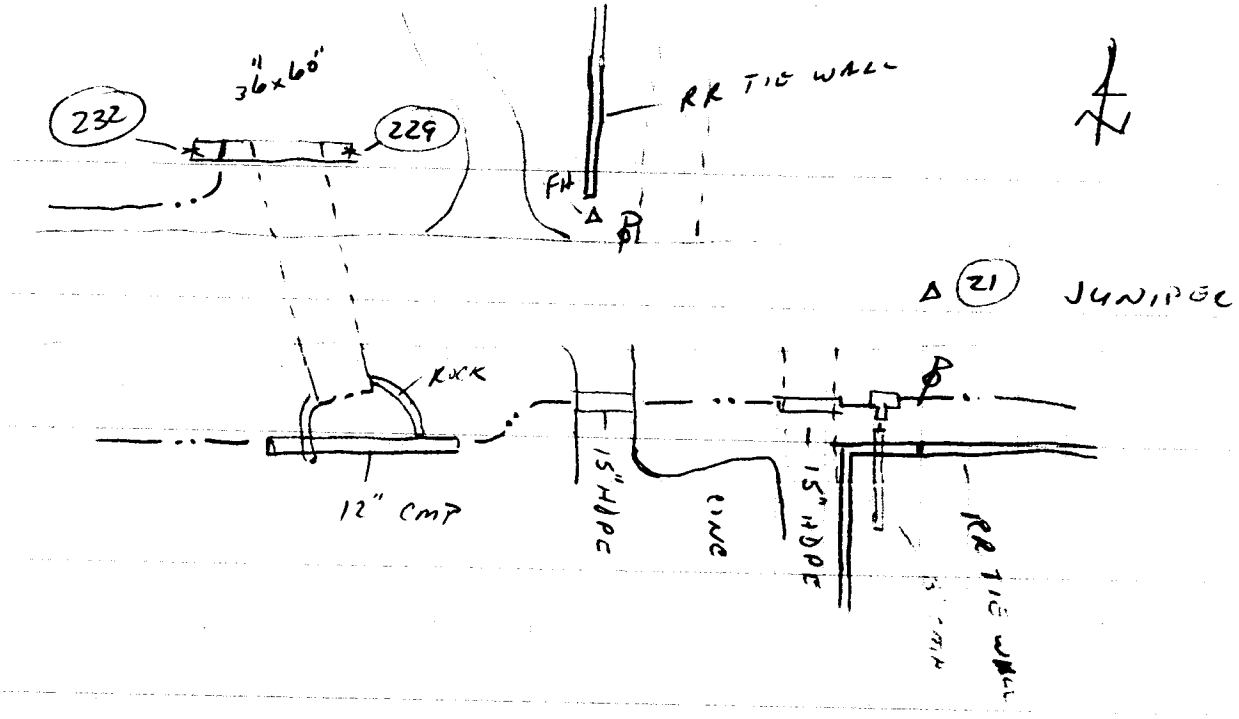
Looking south across Juniper Avenue near culvert crossing

Downstream face of Juniper Avenue culvert

Downstream face of Juniper Avenue culvert

INVERT OUT = 5486.49

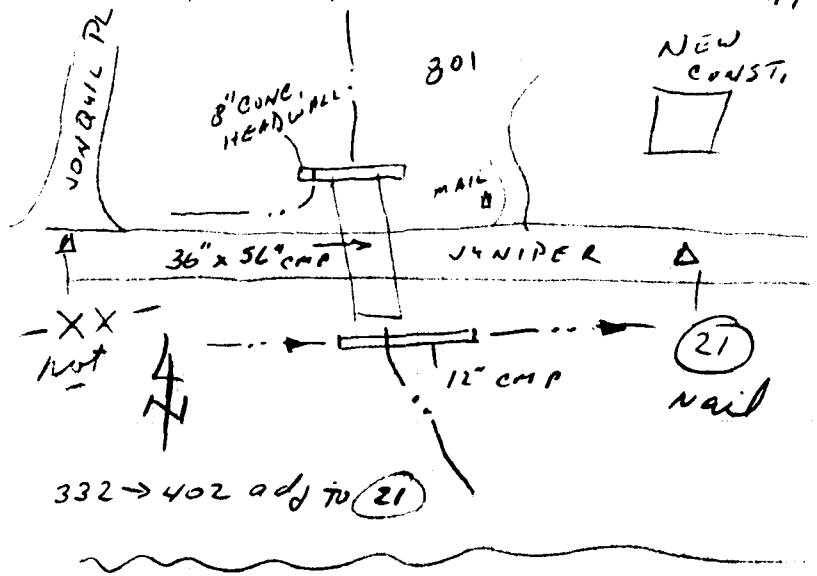
JUNIPER AVENUE - Twomile Canyon Creek


RR TIE WALL
21
JUNIPER
15" HDPE
15" HDPE
RR TIE WALL
12" CMP
232
229
36x60"

AND BOULDER / GOOSE CR

9/16/11 TPF

49



Looking upstream at Kalmia Avenue crossing

Downstream face of Kalmia Avenue crossing

INVERT OUT, 3.0 FT x 5.0 FT CMP = 5511.15

Looking downstream across Kalmia Avenue

Looking east on Kalmia Avenue

Looking west on Kalmia Avenue

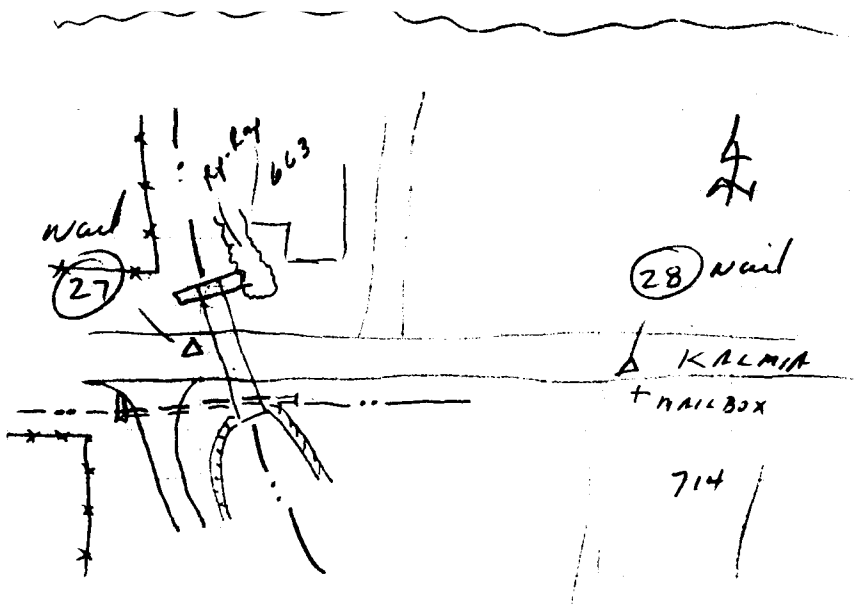
Upstream face of Kalmia Avenue crossing

INVERT IN = 5512.93

HEADWALL CREST = 5517.01

Upstream face of Kalmia Avenue crossing

...AND BOULDER / GOOSE CR 9/16/11 TPF 49



Looking east along Linden Street at the Spring Valley Road intersection

Looking east along Linden Street east of the Spring Valley Road intersection

Looking west along Linden Street east of the Spring Valley Road intersection

Looking upstream at Linden Avenue culvert

Looking upstream at Linden Avenue culvert

INVERT OUT, 14" X 36" CMP = 5558.71

INVERT OUT, 32" X 43" CMP = 5558.53

LINDEN AVENUE - Twomile Canyon Creek

Looking west along roadside drainage swale (south of Linden)

Looking downstream across Linden Avenue

ROADWAY CREST = 5565.13

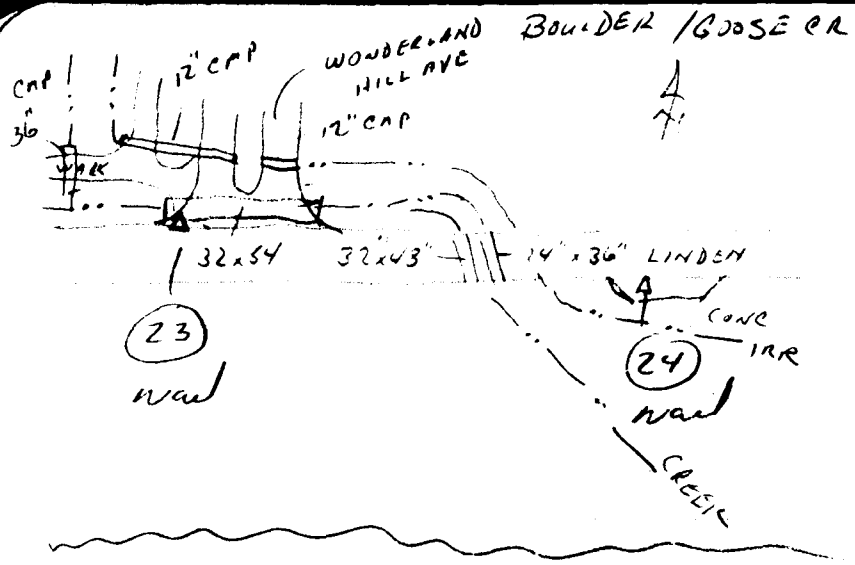
Looking east along Linden Avenue

Looking west along Linden Avenue

Upstream face of Linden Avenue culvert

INVERT IN, 14" X 36" CMP = 5560.74

INVERT IN, 32" X 43" CMP = 5561.89


BOULDER / GOOSE CR
9/16/11
TPF
49
CMP
36"
12" CMP
WONDERLAND HILL AVE
12" CMP
32x54
32x43"
14" x 36" LINDEN
CONC
IRR
23
wall
24
wall
CREEK

Looking upstream towards Spring Valley Road culverts

Looking upstream towards Spring Valley Road culverts

INVERT OUT, 3.0 FT x 5.0 FT CMP = 5599.27

INVERT OUT, 3.0 FT x 5.0 FT CMP = 5598.68

Looking downstream towards Spring Valley Road culverts

INVERT IN, 3.0 FT x 5.0 FT CMP = 5600.25

INVERT IN, 3.0 FT x 5.0 FT CMP = 5599.65

Looking south along Spring Valley Road

ROADWAY CREST = 5605.93

SPRING VALLEY ROAD - Twomile Canyon Creek

Looking upstream at Wonderland Hill Avenue culvert

INVERT OUT, 32" X 54" CMP = 5566.67

WONDERLAND HILL AVENUE - Twomile Canyon Creek

Looking downstream across Wonderland Hill Avenue

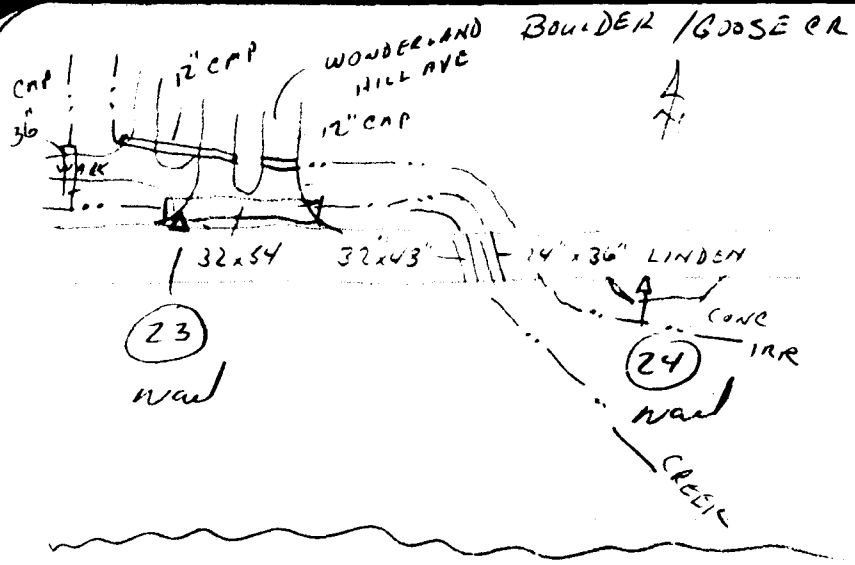
WONDERLAND HILL AVENUE - Twomile Canyon Creek

CREST = 5573.32

Looking downstream at Wonderland Hill Avenue culvert

INVERT IN, 32" X 54" CMP = 5568.86

WONDERLAND HILL AVENUE - Twomile Canyon Creek


BOULDER /GOOSE CR
9/16/11
TPF
49
CMP
36"
12" CMP
WONDERLAND HILL AVE
12" CMP
32x54
32x43"
14" x 36" LINDEN
CONC
IRR
23
24
wall
wall
CREEK

from the HEC-RAS user manual

section and the next cross section downstream, which gives the energy loss caused by the transition (Equation 2-2 of Chapter 2). Where the change in river cross section is small, and the flow is subcritical, coefficients of contraction and expansion are typically on the order of 0.1 and 0.3, respectively. When the change in effective cross section area is abrupt such as at bridges, contraction and expansion coefficients of 0.3 and 0.5 are often used. On occasion, the coefficients of contraction and expansion around bridges and culverts may be as high as 0.6 and 0.8, respectively. These values may be changed at any cross section. For additional information concerning transition losses and for information on bridge loss coefficients, see chapter 5, Modeling Bridges. Typical values for contraction and expansion coefficients, for subcritical flow, are shown in Table 3-3 below.

Table 3-3

Subcritical Flow Contraction and Expansion Coefficients

	Contraction	Expansion
No transition loss computed	0.0	0.0
Gradual transitions	0.1	0.3
Typical Bridge sections	0.3	0.5
Abrupt transitions	0.6	0.8

The maximum value for the contraction and expansion coefficient is one (1.0). **Note: In general, the empirical contraction and expansion coefficients should be lower for supercritical flow**. In supercritical flow the velocity heads are much greater, and small changes in depth can cause large changes in velocity head. Using contraction and expansion coefficients that would be typical for subcritical flow can result in over estimation of the energy losses and oscillations in the computed water surface profile. In constructed trapezoidal and rectangular channels, designed for supercritical flow, the user should set the contraction and expansion coefficients to zero in the reaches where the cross sectional geometry is not changing shape. In reaches where the flow is contracting and expanding, the user should select contraction and expansion coefficients carefully. Typical values for gradual transitions in supercritical flow would be around 0.01 for the contraction coefficient and 0.03 for the expansion coefficient. As the natural transitions begin to become more abrupt, it may be necessary to use higher values, such as 0.05 for the contraction coefficient and 0.2 for the expansion coefficient. If there is no contraction or expansion, the user may want to set the coefficients to zero for supercritical flow.

Appendix B
Manning's 'n' Values
(typical channel)

Looking upstream at typical channel Q

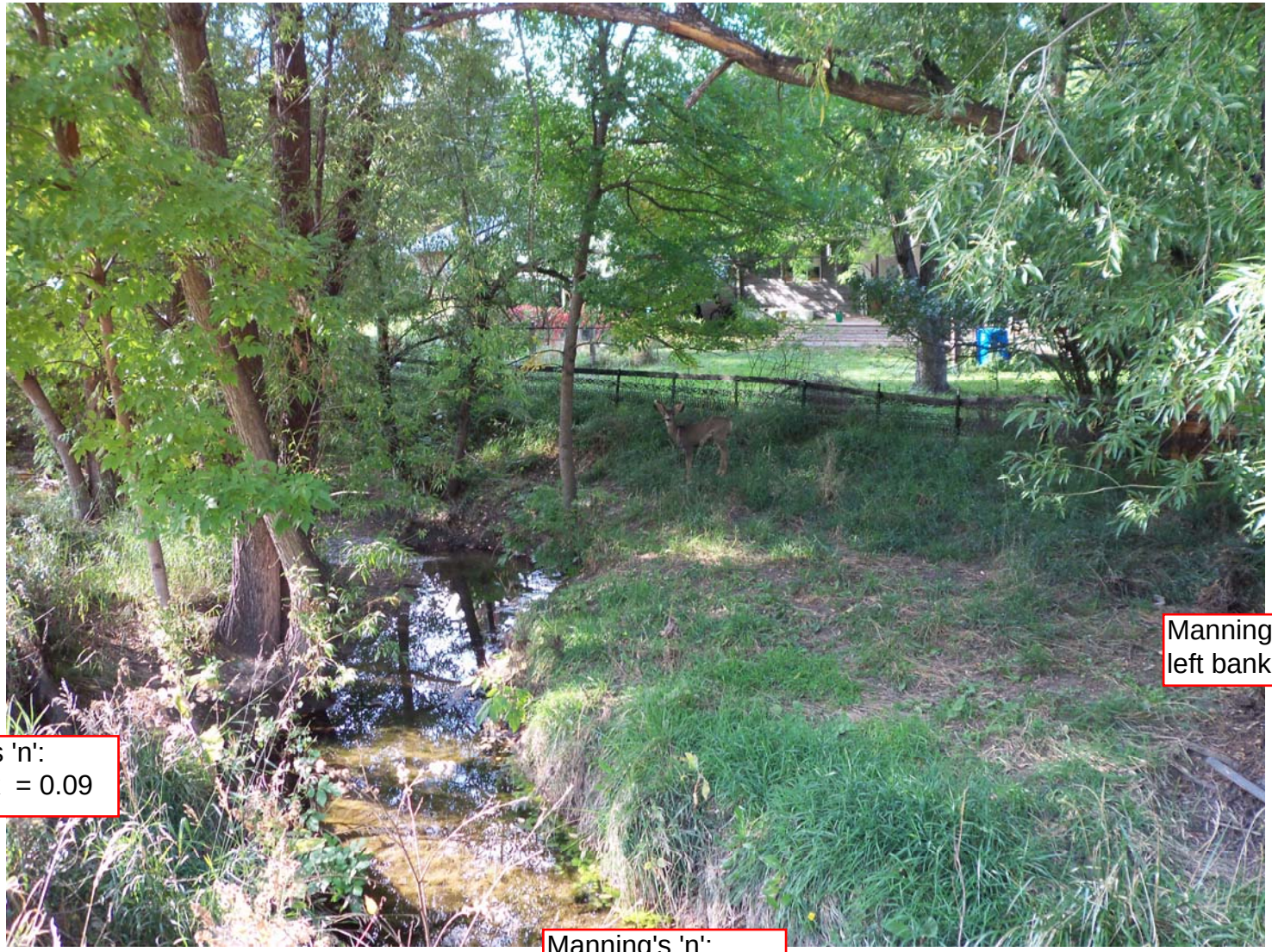
Looking upstream at typical channel R

Manning's 'n':
right bank = 0.09

Manning's 'n':
left bank = 0.09

Manning's 'n':
channel = 0.05

Looking upstream at typical channel S



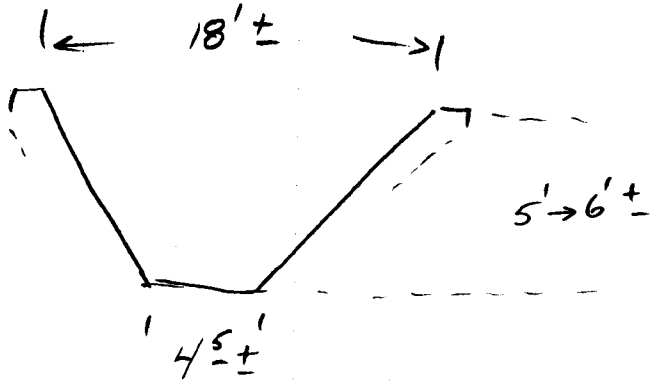
Manning's 'n':
left bank = 0.08

Manning's 'n':
right bank = 0.09

Manning's 'n':
channel = 0.05

Looking upstream at typical channel T

GOOSE / BOULDER



TYPICAL CONC. CHANNEL

Typical Channel (T) Section - Goose Creek

Typical Channel U
Manning's 'n':
left bank = 0.04
channel = 0.015
right bank = 0.04

Typical Channel V
Manning's 'n':
left bank = 0.05
channel = 0.015
right bank = 0.05

Typical Channel W
Manning's 'n':
left bank = 0.06
channel = 0.015
right bank = 0.04

Looking downstream at typical channel A

Manning's 'n':
right bank = 0.05

Manning's 'n':
channel = 0.04

Looking downstream at typical channel B

Manning's 'n':
right bank = 0.05

Manning's 'n':
left bank = 0.04

Manning's 'n':
channel = 0.05

Looking downstream at typical channel C

Manning's 'n':
left bank = 0.10

Manning's 'n':
right bank = 0.10

Manning's 'n':
channel = 0.08

Looking downstream at typical channel D

Manning's 'n':
left bank = 0.10

Manning's 'n':
right bank = 0.10

Manning's 'n':
channel = 0.08

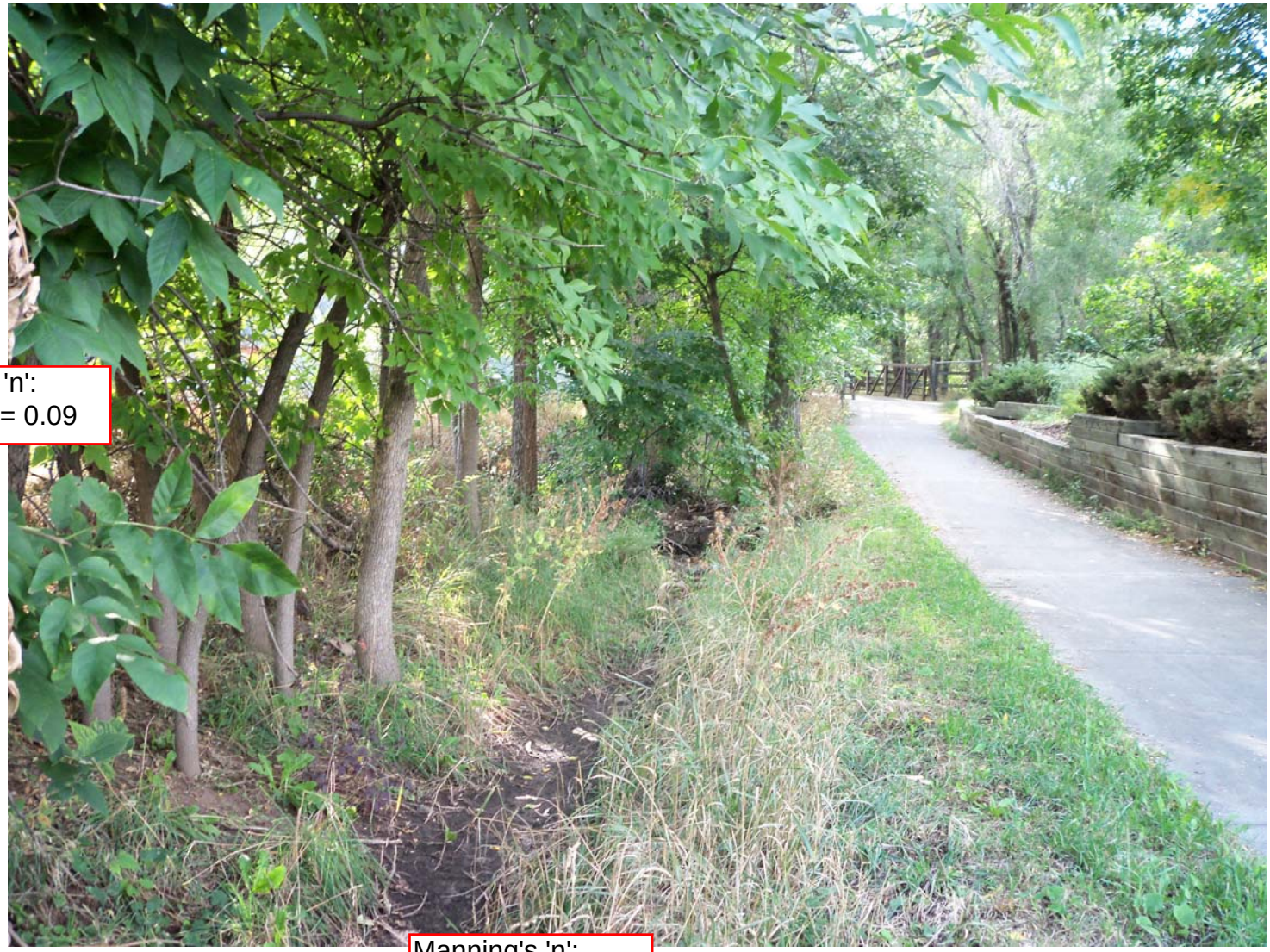
Looking upstream at typical channel E

Manning's 'n':
right bank = 0.09

Manning's 'n':
left bank = 0.09

Manning's 'n':
channel = 0.05

Looking upstream at typical channel F



Manning's 'n':
right bank = 0.09

Manning's 'n':
channel = 0.05

Looking upstream at typical channel G

Manning's 'n':
channel = 0.09

Manning's 'n':
left bank = 0.09

Manning's 'n':
channel = 0.05

Looking upstream at typical channel H

Manning's 'n':
right bank = 0.08

Manning's 'n':
left bank = 0.08

Manning's 'n':
channel = 0.05

Looking upstream at typical channel I

Manning's 'n':
right bank = 0.08

Manning's 'n':
left bank = 0.09

Manning's 'n':
channel = 0.05

Looking upstream at typical channel J

Manning's 'n':
right bank = 0.09

Manning's 'n':
left bank = 0.08

Manning's 'n':
channel = 0.05

Looking upstream at typical channel K

Manning's 'n':
right bank = 0.09

Manning's 'n':
left bank = 0.09

Manning's 'n':
channel = 0.06

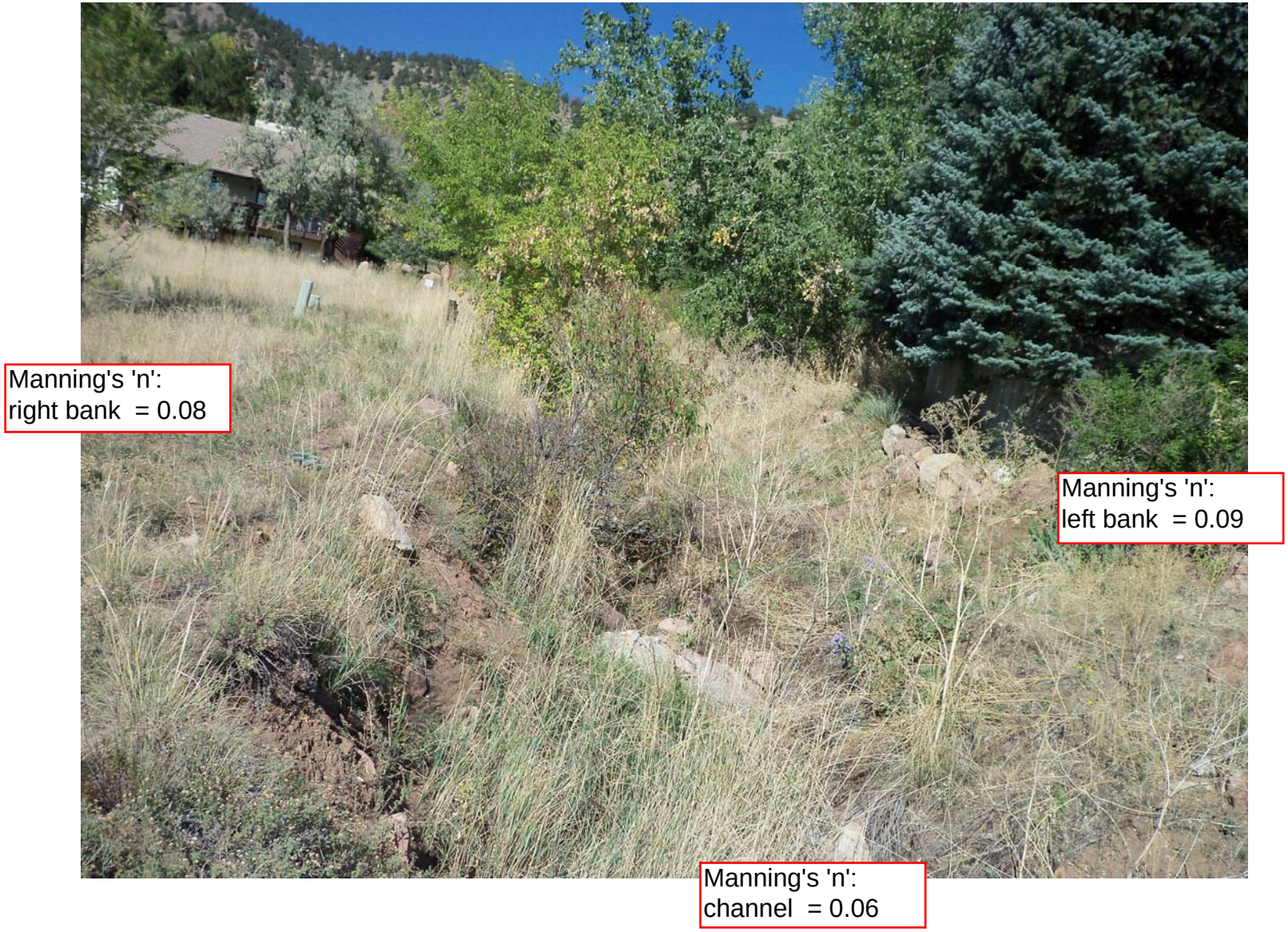
Looking upstream at typical channel L

Manning's 'n':
right bank = 0.08

Manning's 'n':
left bank = 0.08

Manning's 'n':
channel = 0.06

Looking upstream at typical channel M



Looking upstream at typical channel N

Manning's 'n':
right bank = 0.08

Manning's 'n':
left bank = 0.08

Manning's 'n':
channel = 0.05

Looking upstream at typical channel O

Manning's 'n':
right bank = 0.10

Manning's 'n':
left bank = 0.09

Manning's 'n':
channel = 0.06

Looking downstream at typical channel P

Manning's 'n':
channel = 0.05

from Open-Channel Hydraulics by Chow

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT n
(**Boldface** figures are values generally recommended in design)

Type of channel and description	Minimum	Normal	Maximum
A. CLOSED CONDUITS FLOWING PARTLY FULL			
A-1. Metal			
a. Brass, smooth	0.009	**0.010**	0.013
b. Steel			
1. Lockbar and welded	0.010	0.012	0.014
2. Riveted and spiral	0.013	0.016	0.017
c. Cast iron			
1. Coated	0.010	0.013	0.014
2. Uncoated	0.011	0.014	0.016
d. Wrought iron			
1. Black	0.012	0.014	0.015
2. Galvanized	0.013	0.016	0.017
e. Corrugated metal			
1. Subdrain	0.017	0.019	0.021
2. Storm drain	0.021	**0.024**	0.030
A-2. Nonmetal			
a. Lucite	0.008	0.009	0.010
b. Glass	0.009	**0.010**	0.013
c. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
d. Concrete			
1. Culvert, straight and free of debris	0.010	0.011	0.013
2. Culvert with bends, connections, and some debris	0.011	**0.013**	0.014
3. Finished	0.011	0.012	0.014
4. Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
5. Unfinished, steel form	0.012	0.013	0.014
6. Unfinished, smooth wood form	0.012	**0.014**	0.016
7. Unfinished, rough wood form	0.015	0.017	0.020
e. Wood			
1. Stave	0.010	0.012	0.014
2. Laminated, treated	0.015	0.017	0.020
f. Clay			
1. Common drainage tile	0.011	**0.013**	0.017
2. Vitrified sewer	0.011	0.014	0.017
3. Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
4. Vitrified subdrain with open joint	0.014	0.016	0.018
g. Brickwork			
1. Glazed	0.011	0.013	0.015
2. Lined with cement mortar	0.012	0.015	0.017
h. Sanitary sewers coated with sewage slimes, with bends and connections	0.012	0.013	0.016
i. Paved invert, sewer, smooth bottom	0.016	0.019	0.020
j. Rubble masonry, cemented	0.018	0.025	0.030

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

Type of channel and description	Minimum	Normal	Maximum
B. LINED OR BUILT-UP CHANNELS			
B-1. Metal			
a. Smooth steel surface			
1. Unpainted	0.011	**0.012**	0.014
2. Painted	0.012	0.013	0.017
b. Corrugated	0.021	0.025	0.030
B-2. Nonmetal			
a. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
b. Wood			
1. Planed, untreated	0.010	0.012	0.014
2. Planed, creosoted	0.011	0.012	0.015
3. Unplaned	0.011	0.013	0.015
4. Plank with battens	0.012	0.015	0.018
5. Lined with roofing paper	0.010	0.014	0.017
c. Concrete			
1. Trowel finish	0.011	**0.013**	0.015
2. Float finish	0.013	0.015	0.016
3. Finished, with gravel on bottom	0.015	0.017	0.020
4. Unfinished	0.014	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023
6. Gunite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	
8. On irregular excavated rock	0.022	0.027	
d. Concrete bottom float finished with sides of			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry, plastered	0.016	0.020	0.024
4. Cement rubble masonry	0.020	0.025	0.030
5. Dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. Glazed	0.011	**0.013**	0.015
2. In cement mortar	0.012	**0.015**	0.018
g. Masonry			
1. Cemented rubble	0.017	0.025	0.030
2. Dry rubble	0.023	0.032	0.035
h. Dressed ashlar	0.013	0.015	0.017
i. Asphalt			
1. Smooth	0.013	0.013	
2. Rough	0.016	0.016	
j. Vegetal lining	0.030	.....	0.500

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

Type of channel and description	Minimum	Normal	Maximum
C. EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	**0.022**	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0.035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
D. NATURAL STREAMS			
D-1. Minor streams (top width at flood stage <100 ft)			
a. Streams on plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	**0.030**	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

Type of channel and description	Minimum	Normal	Maximum
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
D-2. Flood plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage >100 ft). The n value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	.....	0.060
b. Irregular and rough section	0.035	.....	0.100

from Flo-2D User Manual

Overland flow velocities and depths vary with topography and the grid element roughness. Spatial variation in floodplain roughness can be assigned through the GDS or FLOENVIR processor. The assignment of overland flow roughness must account for vegetation, surface irregularity, non-uniform and unsteady flow. It is also a function of flow depth. Typical roughness values (Manning's n coefficients) for overland flow are shown in Table 1.

Table 1. Overland Flow Manning's n Roughness Values[1]

Surface	n-value
Dense turf	0.17 - 0.80
Bermuda and dense grass, dense vegetation	0.17 - 0.48
Shrubs and forest litter, pasture	0.30 - 0.40
Average grass cover	0.20 - 0.40
Poor grass cover on rough surface	0.20 - 0.30
Short prairie grass	0.10 - 0.20
Sparse vegetation	0.05 - 0.13
Sparse rangeland with debris	
0% cover	0.09 - 0.34
20 % cover	0.05 - 0.25
Plowed or tilled fields	
Fallow - no residue	0.008 - 0.012
Conventional tillage	0.06 - 0.22
Chisel plow	0.06 - 0.16
Fall disking	0.30 - 0.50
No till - no residue	0.04 - 0.10
No till (20 - 40% residue cover)	0.07 - 0.17
No till (60 - 100% residue cover)	0.17 - 0.47
Open ground with debris	0.10 - 0.20
Shallow glow on asphalt or concrete (0.25" to 1.0")	0.10 - 0.15
Fallow fields	0.08 - 0.12
Open ground, no debris	0.04 - 0.10
Asphalt or concrete	0.02 - 0.05

[1]Adapted from COE, HEC-1 Manual, 1990 and the COE, Technical Engineering and Design Guide, No. 19, 1997 with modifications.

Some FLO-2D projects have been model grid elements inside of the channel. In this case, the channel component is not used and instead the FLO-2D grid system is draped over the channel portion of the topography. While these projects have been conducted with some success, there are several modeling concerns that should be addressed. The FLO-2D model was developed to be able to exchange 1-D channel overbank discharge with the floodplain grid elements. For this reason, the model works well on large flood events and large grid elements. When small grid elements are used inside of a channel with confined flow and large discharges and flow depths, the model may run slow. In addition, there will be zero water surface slope between some grid elements. It should be noted that the application of the Manning's equation for uniform channel to compute the friction slope is no longer valid as the velocity approaches zero (ponded flow condition). The resulting water surface elevations can be accurately predicted but will display some small variation across the channel.