MUSEUM FIRE FLOOD – SPRUCE WASH FEASIBILTY STUDY TECHNICAL MEMORANDUM

Date:	March 25, 2022
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Links/Attachments:	Spruce Wash Feasibility Segment Tables, Spruce Wash Feasibility Exhibits

INTRODUCTION

Summer 2021 monsoon rainfall resulted in flooding along Spruce Wash in the Mount Elden Estates, Shadow Mountain (along Paradise Rd.), Grandview Homes and Sunnyside neighborhoods. Flooding was exacerbated by the 2019 Museum Fire which burned a significant portion of the watershed feeding Spruce Wash. This technical memorandum summarizes the feasibility analysis for increasing capacity of drainage infrastructure along Spruce Wash from Route 66 to Linda Vista Drive. This analysis identifies infrastructure constraints and conflicts and proposes approaches to addressing conflicts. The process of determining and analyzing infrastructure has been informed by input from the Technical Advisory Committee (TAC). The TAC includes members from the City of Flagstaff (COF), the Coconino County Flood Control District (CCFCD), Flagstaff Unified School District (FUSD), and engineering consultants. This technical memorandum also considers the recommendations from the Museum Fire Flood Summit (MFFS) held on August 26 & 27, 2021 which consisted of stakeholders from the regulatory and engineering community, statewide.

This memo does not address alternate or multiple conveyance alignments; this memo focuses on maximizing the capacity of Spruce Wash within its current alignment. Analysis of alternate conveyance systems is a future task.

There are four mitigation projects currently in design along Spruce Wash: 1) regional detention basins at Killip Elementary School, 2) culvert crossing at Dortha Avenue, 3) City owned parcel off of Park Way for sedimentation basins, and 4) alluvial fan restoration on US Forest Service land and a 40-acre private parcel. In order for downstream infrastructure to function well, sediment needs to be arrested upstream of the urban area which is the goal of the Park Way sedimentation basins and the alluvial fans. It is imperative to reduce sediment to the extent feasible to maintain downstream capacity and reduce damage and maintenance.

EXISTING CONDITIONS

SPRUCE WASH ALIGNMENT

The extents of Spruce Wash studied for this feasibility analysis are Route 66 at the south end and Linda Vista Drive at the north end. Starting at the downstream end, Spruce Wash is conveyed via a single box storm drain under 1st Street and a single large diameter pipe under Spruce Avenue and 3rd Street. Spruce Wash turns northwest, through the Arroyo Seco Townhomes, then runs in the alley between 1st Street/Main Street and Rose Street, crossing Dortha and Cedar Avenues. The section of the wash between Arroyo Seco townhomes is open channel with a large diameter pipe below. The reach between Dortha and Cedar Avenue is open channel. From Cedar Avenue, Spruce Wash runs in the alley between Grandview Drive and Monte Vista Drive until it reaches Linda Vista Drive at the north end. Upstream of Linda Vista Drive, Spruce Wash is natural channel.

SPRUCE WASH INFRASTRUCTURE

Existing storm drainage infrastructure along Spruce Wash between Route 66 and Linda Vista Drive generally consists of the following:

- Box storm drains, various sizes, from Route 66 to just south of the intersection of 1st Street and Spruce Avenue.
- 60" storm drain below Spruce Avenue, 3rd Street and through a tract and paved private street of Arroyo Seco Townhomes.
- Combination 60" storm drain and open channel (unimproved, roughly 'U' shaped) in the alley, at the back of parcels, between 1st Street/Main Street and Rose Street, ending at Dortha Avenue
- Open channel (unimproved, roughly 'U' shaped) in the alley, at the back of parcels, between Main Street and Rose Street, between Dortha Avenue and Cedar Avenue
- Box culvert crossing Cedar Avenue
- Open channel (unimproved, roughly 'U' shaped) in the alley, at the back of parcels, between Grand View Drive and Monte Vista Drive.
- Two culverts crossing Linda Vista Drive.

PROJECTS UNDERWAY

The following projects are currently underway:

- Existing conditions hydrology and hydraulic analysis. J.E. Fuller is refining the hydrology of the Spruce Wash watershed and analyzing the hydraulics of the existing primary storm drainage infrastructure. This analysis will inform the Spruce Wash infrastructure needs.
- Killip Detention Basins. Shepherd-Wesnitzer Inc. (SWI) is designing two regional detention basins at Killip Elementary School. These basins will be 4-ft deep and hold approximately 11-acre-ft of stormwater. A portion of runoff from Spruce Wash will flow through Ponderosa Park to the basins. The basins will outlet to a new 60" diameter storm drain along 6th Avenue that connects to the Spruce Wash storm drain in 3rd Street.

- Dortha Crossing & Channel. SWI is designing a single barrel box culvert (12'x8') crossing at Dortha and channel improvements between Dortha Avenue and Cedar Avenue.
- Park Way Sedimentation Basins. Natural Channel Design (NCD) is designing sedimentation basins on a long and narrow 3.6-acre City-owned parcel north of Linda Vista Drive.
- Alluvial Fans. NCD is designing alluvial fans upstream of Mount Elden Estates and between Mount Elden Estates and the cul-de-sac of Paradise Road.

TARGET FLOW RATE

The 2019 Museum fire compromised the watershed and changed the hydrologic conditions. Ordinarily, an analysis of this type would conform to the City's Stormwater Management Design Manual for a specific storm event (100-year storm is typically used for sizing infrastructure of this type). However, the burn scar produces a much higher discharge rate than an unburned watershed for the same design storm. It is the consensus of the MFFS and the TAC that infrastructure designed for a post-burn 100-year design storm is likely not feasible because it would result in infrastructure that is 1) oversized for a recovered watershed, and 2) is likely cost prohibitive for both property acquisition and infrastructure improvements. The goal of this initial feasibility analysis is to maximize the capacity of Spruce Wash along its current alignment.

A flow rate of 1,278-cfs was selected as the target for sizing infrastructure. This design flow is based on the Northeast Area Master Drainage Study (NEAMDS) 100-year estimated runoff at Route 66. Since the NEAMDS estimated discharge at Route 66 is 1,278-cfs, upstream infrastructure should not contribute more flow than this at the railroad crossing south of Route 66. The 1,278-cfs is within 2%-5% of the post-fire discharge rate that J.E. Fuller estimated for the 25-year, 6-hour SCS Type II design storm and the 2" rain distribution in their 2019 model.

CONSTRAINTS & CONFLICTS

For this feasibility analysis, infrastructure constraints and conflicts are grouped into the following categories:

- Topography – existing topography drives the available slope and cover for storm drainage infrastructure.
- Boundaries – property boundaries and easements impact project cost due to easement or property acquisition. This analysis does not consider full parcel acquisition. Where existing easements appear to be lacking or are undefined, this analysis assumes that additional easements can be obtained.
- Utilities – sewer, storm drains, water, gas, power, and communication.
    - At storm drain/sewer main crossings, proposed storm drains are designed to run below existing sewer mains and services to avoid conflict. Where conflicts are unavoidable, sewer mains are realigned.
    - Existing storm drain connections are maintained.

- While water, gas, power, and communication will be considerations for the design as it progresses, they were not considered constraints to the physical location of the infrastructure; it is assumed that they can be relocated.

- Structures & buildings – design of storm drain infrastructure avoids major structures/buildings, but may impact sheds and fences.

HYDRAULIC METHODOLOGY & ASSUMPTIONS

Capacity of upstream infrastructure is limited by the capacity of downstream infrastructure, unless there is detention. In general, drainage infrastructure should be upsized from downstream to upstream.

Capacity of downstream systems could be reduced by contributing flow from intersecting storm drain systems serving different watersheds. Notably, runoff from the West Street wash and from 4th Street join the Spruce Wash storm drain system at 1st Street and 3rd Avenue, respectively. JE Fuller's existing conditions analysis includes the time to concentration of these intersecting systems. Preliminary results from J.E. Fuller's model indicates that the peak flows coincide. This will limit the capacity of the proposed infrastructure to convey runoff from Spruce Wash but will increase overall system capacity.

For hydrology, a hydrograph from J.E. Fuller's 2019 FLO-2D model of the of the 2" rainfall distribution upstream of Linda Vista Drive was routed through the storm drain system. The peak of the hydrograph is 1,298-cfs, which closely compares to the target design flow of 1,278-cfs.

STORM DRAINS

Box storm drains were analyzed using Autodesk Storm and Sanitary Sewer Analysis 2019. A roughness coefficient, n=0.015, was used for concrete. Flow was routed using hydrodynamic routing calculations.

Capacities are shown based on full pipe flow and not pressure pipe flow. Bends in the channel and box culverts are assumed to be radiused and bend losses are neglected. Junctions at changes in slope and angle points assume boxes are directly connected without vaults; therefore, junction losses are neglected. An exit loss of 0.5 was used at box culvert expansions. Maintenance access is assumed to be from manholes mounted to the top of boxes.

Clogging was not accounted for in sizing of the box storm drains. Storm drain velocities at full flow are greater than cleansing velocity of 3-ft/sec and range between 11-ft/sec to 25-ft/sec.

CULVERTS

Note: the draft feasibility analysis included box culverts at Linda Vista Drive and Cedar Avenue. These have been replaced by a continuous box storm drain from Cedar Avenue to above Linda Vista Drive. The hydraulic criteria below are for documentation but no longer pertain to the final concept design. Since the box storm drain is set below the flow line of the existing channel, culverts are needed at Linda Vista Drive and at Cedar Avenue above the box storm drain. These culverts will convey runoff between the open channels at these street crossings from localized drainage and when flow exceeds the capacity of the box culvert. Design flow, sizing and configuration of the culverts has not been determined.

Culverts at Linda Vista Drive and Cedar Avenue were analyzed using FHWA's HY-8 software. Culverts were modeled using lower (765-cfs), middle (1,298-cfs), and upper (2,569-cfs) flows[1]. A roughness coefficient, n=0.015, was used for Manning's roughness for concrete. The middle flow is close to the target flow rate bench for design of proposed improvements.

Inlet losses are minimized, assuming a beveled headwall with wing walls (Ke=0.2). Inlets assume no trash racks or sediment clogging. In the absence of a specific design flow, culvert capacity was assumed to be reached when the roadway overtopped and not limited to the maximum HW/D per City of Flagstaff requirements. Since modeling assumes that culverts reach capacity when the roadway overtops, the water surface elevation immediately upstream of the culvert is assumed equal to the roadway elevation. Buildings upstream of the culverts and adjacent to the channel are assumed to have higher finished floor elevations than the roadway and are therefore above the water surface. During storm events greater than the culvert capacity and when the roadway overtops, the water surface elevation will be higher. *Detailed survey of the adjacent finished floors and elevations of the top of roadway and channel should be conducted to confirm these assumptions.*

Upstream channels were assumed to slope down to the culvert inlet at a consistent slope rather than having the culvert inlet depressed. At the Linda Vista Drive crossing, the culvert invert is ~5'-6' below the channel bottom; a depressed culvert inlet could be considered based with channel grading. Next steps should include detailed cross section analysis (HEC-RAS) to evaluate the effects of headwater ponding.

OPEN CHANNEL

Note: the draft feasibility analysis included open channel between Linda Vista Drive and Cedar Avenue. The open channel has been replaced by a continuous box storm drain. An open box channel presents safety concerns and would require railing, ladders and additional capacity for freeboard. This results in a larger structure and greater property impacts; therefore, a closed box system is preferred. The hydraulic criteria below are included for documentation but no longer pertain to the final concept design. The box storm drain is set below the flow line of the existing channel between Linda Vista Drive and Cedar Avenue allowing for an open channel above the box culvert. It is assumed that the open channel can convey localized runoff; the channel design and its capacity is not included in this study.

The channel between Linda Vista Drive and Cedar Avenue was analyzed using Autodesk Hydraflow Express which models 1-dimensional channel cross sections based on slope, depth, and Manning's roughness.

The goal for this feasibility study is to maximize conveyance along Spruce Wash. A trapezoidal channel with a 14-ft bottom width, 6-ft depth and 2:1 side slopes (total width of 38-ft), was selected because it generally fits the footprint of the existing 'U' shaped channel based on 2019 LIDAR contour data and the

[1] The lower to upper flows are from J.E. Fuller's 2019 Museum Fire FLO-2D modeling for the 10-year (765-cfs), 25-year (1,298-cfs), and 100-year (2,569-cfs), 6-hour, SCS Type II Design Storms. These flows were selected because the 25-year design storm is relatively close to the target flow rate and to provide lower and upper flow bounds that reflect modeled conditions.

variable width easement. Field observations indicate that the distance between fences and walls is narrower than the typical channel in some areas. As the design is refined, the typical channel will be modified to better fit field conditions and limit impact to fences and walls. Channel side slopes can be steepened in constricted locations.

The proposed channel centerline and profile are assumed to generally follow the thalweg of the existing channel except at transitions to the box culverts at Linda Vista Drive and Cedar Avenue. Existing channel slopes vary between 0.75% and 3%.

A concrete channel with either concrete or grouted riprap sides is recommended to maximize channel capacity, ease of maintenance and stability.

Two Manning's roughness coefficients were selected for the channel: concrete (Manning's n = 0.015) or a combination of a concrete bottom with grouted riprap sides (Manning's n = 0.023). The channel option that maximizes the capacity is the concrete option. The combination of concrete with grouted riprap sides helps reduce velocity when channel slopes are steeper compared to a fully concrete channel.

The channel slope and lower Manning's roughness produce supercritical flows with velocities between 15-ft/sec and 25-ft/sec. Since flows are supercritical and velocities are relatively high, a minimum of 2-ft of freeboard is recommended.

In general, a concrete channel is suitable for slopes <1.5% and a concrete channel with grouted riprap sides is suitable for sections >1.5%. At slopes between 1% and 2.5%, a hardened channel can convey the target flow rate with 2-ft of freeboard. At slopes less than 1.5%, the combined concrete and grouted riprap channel has reduced freeboard at the target flow rate. As the channel changes slope between the Linda Vista Drive and Cedar Avenue crossings, the type of armoring on the side slopes should change to balance adequate freeboard with channel velocities.

DESIGN CRITERIA AND VARIANCES

The City of Flagstaff Stormwater Management Design Manual (SWMDM) is used as the basis of design for the proposed infrastructure. Design criteria for box storm drains allows for full box flow and requires bends at curves.

The SWMDM requires storm drain sizes to increase in the downstream direction. The box storm drain south of Dortha Avenue is reduced in height from 8' to 6'. A steeper box slope allows for more conveyance in a smaller box. This will require a waiver to the design standards.

Construction of the box storm drain along 1st St requires re-routing of the existing 10" sewer main. The re-routed sewer main will cross two existing storm drains. Additionally, the storm drain box along Spruce Avenue will cross a sewer main at 2nd Street. The separation between the existing and proposed box storm drains and the sewer main in these locations is likely less than 12". This will require a waiver to the design standards.

PROPOSED MITIGATION

The downstream end of the proposed infrastructure is the existing ADOT double box culvert crossing at Route 66. Replacement of the ADOT double box culvert is not proposed. The estimated capacity of the ADOT box culvert is 1,100-cfs+/-, which is close to the target design flow. Upsizing the double box culvert would likely require replacing downstream infrastructure, including a 29' x 8' metal box and headwall and other newly installed improvements at the outfall.

The proposed infrastructure consists of box storm drains from Route 66 to Linda Vista Drive. The estimated capacity of the proposed infrastructure is between 1,100 and 1,800-cfs. Storm drain capacity is presented assuming full pipe flow and that pipes are not under pressure flow conditions. Constraints and conflicts have been identified from plats, as-built plans, City of Flagstaff GIS information, site visits, and utility maps.

The proposed infrastructure is presented in segments beginning at Route 66 in the Spruce Wash Feasibility Segment Tables included with this memorandum.

CONCLUSION & NEXT STEPS

The goal of the feasibility study is to maximize the existing Spruce Wash drainage infrastructure along the Spruce Wash corridor. Based on modeling and constraints, at a feasibility level, the proposed storm drainage system could convey 1,100-cfs+/- from Linda Vista Drive to Route 66 in a continuous box storm drain. For a continuous box storm drain system, further discussion is needed on the access to and maintenance of such a system.

NEXT STEPS

Outstanding tasks and next steps for this feasibility study include:

- Estimate construction costs for financial feasibility.
- Review JE Fuller's model results.
- Evaluate possible phasing/construction sequencing, including evaluation of the Killip Detention basins as either in-line or off-line detention.
- Review alternate conveyance alignments identified during the Museum Fire Flood Summit.
- Conduct a no adverse impacts (NAI) analysis for the proposed storm water infrastructure (to be completed by others).
- Prepare 15% design plans for the proposed storm water infrastructure.

END

SEGMENT 1 – 1ST ST FROM ROUTE 66 TO SPRUCE AVE

Segment 1 begins at the existing ADOT box culvert crossing (double 8' x 7') and ends south of the intersection of 1st St, Maple Ave and Spruce Ave, see Figure 1.

Summary					
Location	**Improvement**	**Length**	**Minimum Slope**	**Cover**	**Capacity**
		(ft)	(%)	(ft)	CFS
1st St	16' x 7' Precast Concrete Box	290	0.37	1' – 1.5'	1,200 +/-

Notes:

- Segments 1 & 2 limit the amount of runoff that the system can convey due to existing storm drain connections, pipe slope, utility conflicts, and other constraints.
- Box storm drain span and height are similar to the ADOT box crossing Route 66 (double 8' x 7')
- Two existing sewer mains (10") join near the intersection of Spruce Ave. and 1st St. These sewer mains cross the Spruce Wash storm drainage infrastructure and limit the height available for the storm drain. In order to maximize the proposed storm drain capacity, these two sewer mains would need to be realigned parallel to the proposed storm drain, one on each side.

Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**
Topography			
	Roadway Slope	The slope of 1st St is 0.5%	The proposed storm drain box slope is less than the roadway slope.
Boundary/property/easement			
	Double D Tire drainage easement (west corner of Route 66 & 1st St, APN 107-12-003A)	The existing storm drainage infrastructure crosses the corner of Double D Tire's parcel. There is a drainage easement along the northeast property line parallel to 1st St. The existing ADOT Box may be outside of easement.	Design should include a boundary and right of way survey to determine easement limits and if an additional easement is needed.
	Double D Tire utility easement (west corner of Route 66 & 1st St, APN 107-12-003A)		Parallel sewer from 1st St will require a utility easement to cross the Double D Tire parcel.

Figure 1

Spruce Wash Feasibility Segment Tables

Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**
Utilities			
	ADOT Double Box Culvert	The invert of the ADOT box culvert controls the design.	Maintain invert.
	Sewer Main Crossing from 1st St., North of Maple	Sewer main in 1st St, north of Maple, crosses the storm drain. Should this sewer line remain, the new storm drain box would be substantially limited in height and capacity. The sewer main crosses the 60" and 72" culvert with less than one foot of separation.	Re-route sewer main to run parallel to the south side of the proposed storm drain box, under the 1st St sidewalk and across Route 66, to tie into the 14" sewer main on the south side of Route 66. Re-routing the 1st St sewer main allows for reconfiguration of an existing sewer main on the north side of Route 66. The Route 66 sewer main currently crosses through the bottom of the double 8'x7' ADOT box culvert; this crossing could be eliminated.
	Sewer Main in 1st St.	The 10" sewer main in 1st St runs parallel to the proposed storm drain box which limits the available width for new storm drain box on the southwest side of 1st St.	Shift the sewer main north to accommodate the proposed storm drain box.
	60" Storm Drain from Johnson Ave.	An existing 60" RCP storm drain connects to the existing box culverts from the southwest side of 1st St.	Maintain invert.
	72" Storm Drain from West St Wash	An existing 72" RCP storm drain connects to the existing box culverts in 1st St.	Maintain invert.
	Gas Main	The new storm drain would cross gas mains near the intersection of 1st St and Spruce Ave. Unisource maps show a gas main along the north side of 1st which is not anticipated to conflict with the proposed improvements.	Mark and pothole utilities. Gas main relocation may be required.
Structure/Building			
	Office Building	Hubbard-Merrell's office building is ~15-ft south of the lip of curb, limiting the ability to widen to the south.	Maintain separation from building, align sewer main under sidewalk.
Other Constraints			
	Traffic Signal Pole	The traffic signal pole on the west corner of the intersection of Route 66 and 1st St is within 10-ft of the existing box culvert.	Avoid traffic signal pole with box storm drain, if possible.
	Storm Drain Box Size Limitation	The 16' wide storm drain box maximizes the available width and capacity. Jensen precast makes "jumbo" box culvert sizes (14'-24' wide); however, production of the jumbo boxes is limited to the concrete form location which adds to the project cost.	
Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**

SEGMENT 2 – SPRUCE AVE FROM 1ST ST TO 3RD AVE

Segment 2 begins on Spruce Avenue at Segment 1 and ends at 3rd Ave, see Figure 2.

Summary					
Location	**Improvement**	**Length**	**Minimum Slope**	**Cover**	**Capacity**
		(ft)	(%)	(ft)	CFS
Spruce Ave	16’ x 6’ Precast Concrete Box	1,250’	0.5%	4’-7’	1,100 +/-
Notes: • Segments 1 & 2 limit the amount of runoff that the system can convey due to existing storm drain connections, pipe slope, utility conflicts, and other constraints. • The top of the box storm drain is set below existing sewer main elevation to maintain sewer service connections.					

Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**
Topography			
	Roadway Slope	Sections of Spruce Ave roadway slope < 0.5%	Storm drain infrastructure slope is limited by the roadway slope.
Boundary/property/easement			
	Parcel 107-04-025A (east corner of 1st St. & Spruce Ave.)	The proposed box storm drain crosses diagonally from 1st St to Spruce Ave near the parcel.	Survey parcel 107-04-025A to determine available easement or right of way.
	Parcel 107-04-033A (southwest corner of Spruce Ave. & 3rd St)	The proposed box storm drain crosses adjacent to the parcel.	Survey parcel 107-04-033A to determine available easement or right of way.
	Temporary easement or right of way along the north side of Spruce Ave.	The width of the proposed box culvert may extend outside the existing 50-ft right-of-way or construction may require a temporary construction easement for trenching.	Survey right-of-way. Obtain temporary construction easement or acquire additional right of way.
Utilities			
	Sewer Main Crossing from Spruce Ave.	The sewer main from Spruce Ave crosses the proposed storm drain box. Maintaining the sewer main alignment would considerably reduce the box storm drain size and capacity.	Re-route the sewer main to run parallel to the north side of the proposed box storm drain.
	Sewer Main Crossing from 2nd St.	The sewer main crossing clears the box culvert with less than one foot of separation.	Design variance needed for not meeting separation requirements.
	Sewer Main & Services in Spruce Ave.	The sewer main in Spruce runs parallel to the proposed box storm drain.	Maintain box height to allow sewer services to be maintained over the top of the proposed box.
	Storm Drain	A 60” storm drain from 4th St joins the Spruce Wash storm drain just south of 3rd Avenue.	Connect to 60” storm drain.
	Natural Gas	Unisource’s utility map shows a gas main along the south side of Spruce Ave.	Gas services will cross the box culvert and may need to be realigned.

Figure 2

Spruce Wash Feasibility Segment Tables

Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**
Structure/Building			
	Parcel 107-04-030, 2320 Spruce, has a garage that is close to the gutter.	Depending on final storm drain configuration the garage will either need to be structurally supported or removed and replaced with the storm drain construction.	

Spruce Wash Feasibility Segment Tables

SEGMENT 3 – 3RD ST FROM SPRUCE AVE TO KILLIP

Segment 3 begins at Spruce Ave and ends at Killip Elementary School, see Figure 3.

Summary					
Location	**Improvement**	**Length**	**Minimum Slope**	**Cover**	**Capacity**
		(ft)	(%)		CFS
3rd St	12’ x 6’ Precast Concrete Box	2,125’	1.3% - 2.7%	3’ - 9’	1,200 - 1,800 +/-
Notes: • The top of the proposed box storm drain is lower in elevation than the existing sewer main.					

Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**
Topography			
		Generally follows existing grade (1%-3%)	
Boundary/property/easement			
		Follows existing right of way	
Utilities			
	Sewer Main & Services in 3rd St	The sewer main in 3rd St runs parallel to the proposed box storm drain.	Maintain elevation of the top of proposed box storm drain equal to or lower than sewer main to avoid sewer service conflicts. Maintain 24” of separation between sewer manholes and the proposed box storm drain.
	60” Storm Drain from 3rd Ave./4th St	An existing 60” storm drain joins the Spruce Wash storm drain from the east via 3rd Ave.	Maintain invert and connect to proposed box storm drain.
	Natural Gas	No natural gas mains are shown parallel to 3rd St on Unisource maps, there are gas main crossings at 2nd Ave and 6th Ave.	Mark and pothole utilities. Gas main relocation may be required.
Structure/Building			
		There are no anticipated impacts.	

Figure 3

SEGMENT 4 – KILLIP FROM 3RD ST TO PONDEROSA PARK

Segment 4 crosses the northeast corner of Killip Elementary School, beginning at 3rd St and ending at Ponderosa Park, see Figure 4.

Summary					
Location	**Improvement**	**Length**	**Minimum Slope**	**Cover**	**Capacity**
		(ft)	(%)	(ft)	CFS
Killip	12’ x 6’ Precast Concrete Box	540’	1.4%	1’	1,300 +/-
Notes: • FUSD indicated that running the storm drain across Killip’s northeast corner was acceptable. This alignment avoids utility conflicts in Arroyo Seco’s drive, which is an alternate alignment.					

Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**
Topography			
		Generally follows existing grade	
Boundary/property/easement			
	Flagstaff Unified School District	The proposed box storm drain crosses private property.	Seek a drainage easement from FUSD.
Utilities			
		No known conflicts.	
Structure/Building			
		There are no anticipated impacts.	
Other infrastructure			
	Killip infrastructure	Killip Elementary School is under construction. The design plans show a fire lane and basketball courts in the area of the proposed box storm drain alignment.	Installation will require reconstruction of newly installed surface improvements.

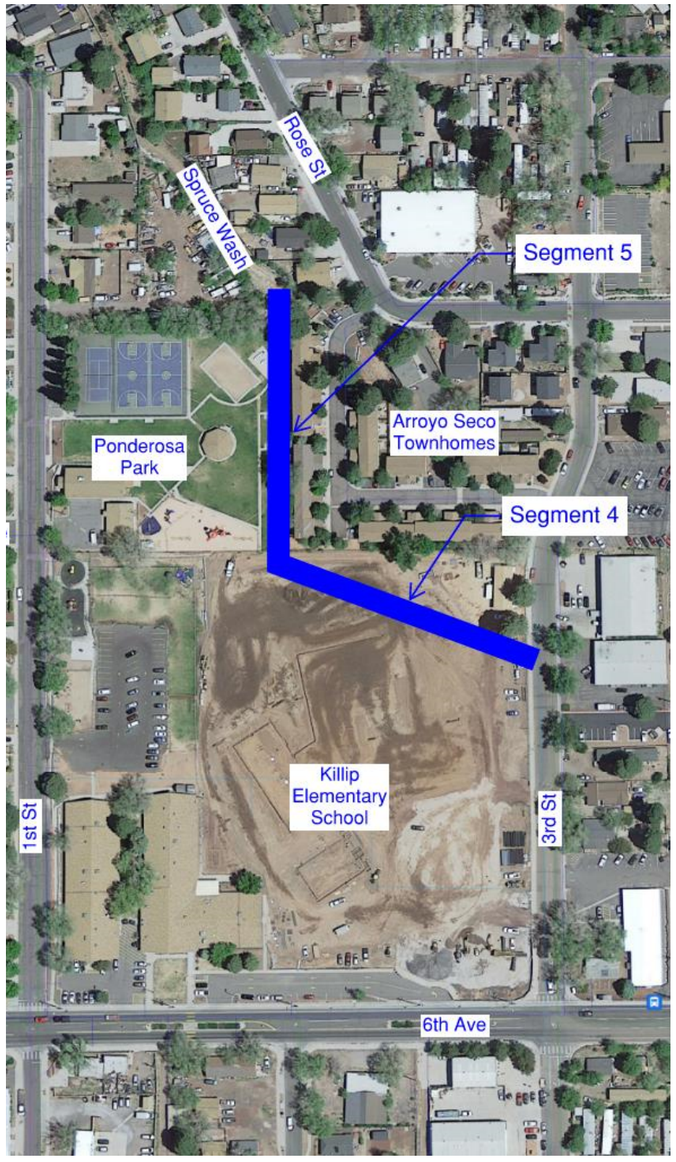

Figure 4

SEGMENT 5 – PONDEROSA PARK FROM KILLIP TO ARROYO SECO INLET/ALLEY

Segment 5 begins at Killip Elementary School and ends at the Arroyo Seco Inlet/Alley, see Figure 5.

Summary					
Location	**Improvement**	**Length**	**Minimum Slope**	**Cover**	**Capacity**
		(ft)	(%)	(ft)	CFS
Ponderosa Park	12’ x 6’ Precast Concrete Box	490’	1.5%	1’ – 1.5’	1,300 +/-
Notes: The existing 60” pipe through Arroyo Seco Townhomes could be maintained and used for local drainage and/or excess runoff not conveyed by the proposed box storm drain. Final design will include a connection from Segment 5 to the Killip detention basins.					

Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**
Topography			
		Generally, follows existing grade	
Boundary/property/easement			
	Parcel 109-09-058 (northeast corner of Ponderosa Park)	The proposed box storm drain crosses parcel 109-09-058; it is unknown if there is a drainage easement.	Seek a drainage easement from the property owner.
Utilities			
	Overhead Power & Communication Lines	Construction of the box storm drain will conflict with overhead utilities and utility poles.	Relocate overhead power and communications lines underground.
Structure/Building			
		There are no anticipated impacts.	
Other infrastructure			
	Ponderosa Park	There are amenities in Ponderosa Park that would need to be replaced or relocated. Specifically, picnic tables and horseshoe pits.	

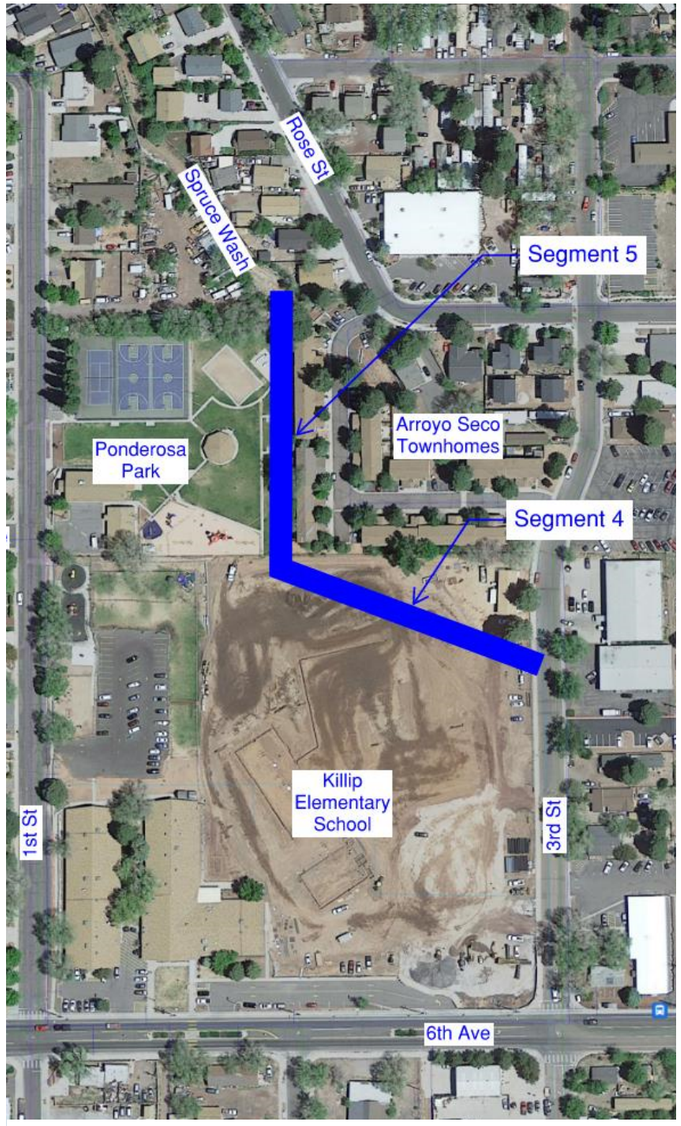

Figure 5

SEGMENT 6 – ALLEY FROM ARROYO SECO TO DORTHA

Segment 6 begins at the Arroyo Seco Townhomes and ends at Dortha Avenue and runs in the alley between 1st St/Main St and Rose St, see Figure 6.

Summary					
Location	**Improvement**	**Length**	**Minimum Slope**	**Cover**	**Capacity**
		(ft)	(%)	(ft)	CFS
Alley, Arroyo Seco to Dortha	12’ x 6’ Precast Concrete Box	1,030’	1.5%-2%	1’ - 2’	1,300 +/-
Notes: This section of Spruce Wash is open channel with an existing 60” storm drain generally centered on the middle of the channel. The installation of a box storm drain would replace the 60” pipe and still allow for a shallow open channel above to capture localized drainage from the adjacent properties.					

Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**
Topography			
		This segment follows the general alignment and slope of the existing open channel.	
Boundary/property/easement			
	Drainage Easement	The Sunnyside North Annex No. 7 and No. 8 plats show a variable width, sinuous drainage easement in the alley/channel with a width up to 50’. There are fences and walls parallel to the channel; widths across the channel between fences/walls are approximately 15’ and 45’ and do not appear to follow the drainage easement.	Conduct a boundary survey and define a drainage easement. Fences and/or walls may need to be relocated.
Utilities			
	Gas Main	Unisource Energy Services, UES, owns a gas main in the alley.	Mark and pothole gas main. Align the drainage improvements to avoid gas main, if possible and relocate gas main if necessary.
	Overhead Power & Communication Lines	Construction of the box storm drain will conflict with overhead utilities and utility poles.	Relocate overhead power and communications lines underground.
	Dortha Box Culvert Crossing (Segment 7)	A new box culvert crossing Dortha Ave is currently being designed with an anticipated construction date of April 2022.	Match downstream invert of the Dortha box culvert, approximately 10’ below existing ground.
Structure/Building			
		There are no anticipated impacts.	

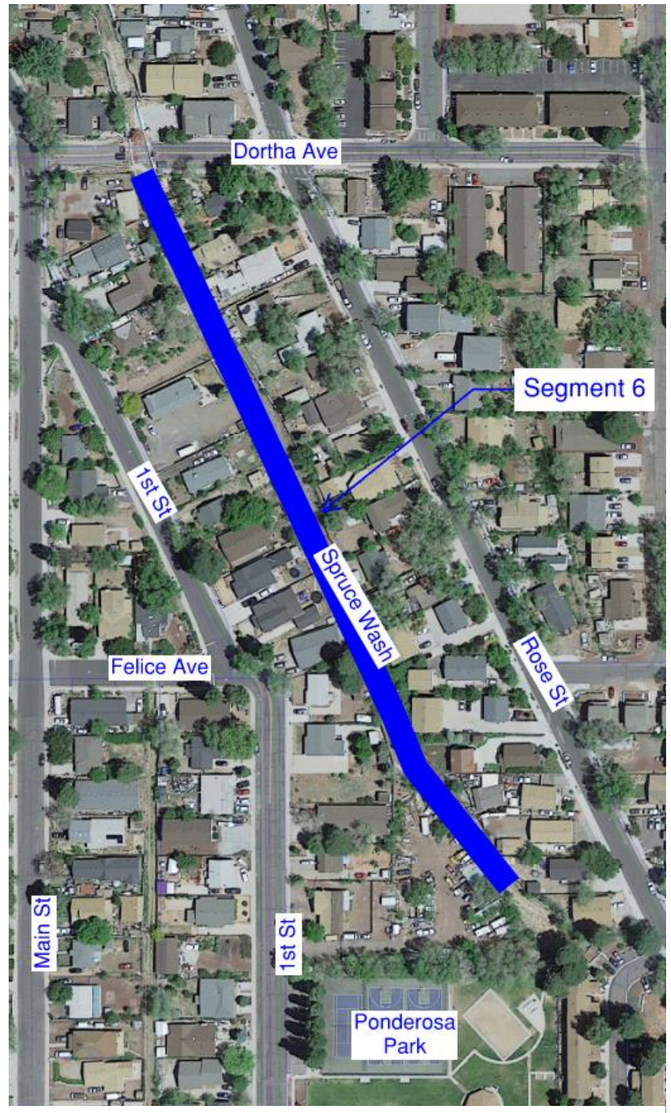

Figure 6

SEGMENT 7 – DORTHA AVE

Segment 7 is a new box culvert (12’ x 8’) crossing at Dortha Ave. which is being designed by Shepherd-Wesnitzer, Inc. for installation in 2022.

(NOTE: there is no figure 7)

SEGMENT 8 – ALLEY FROM DORTHA TO CEDAR

Segment 8 begins at Dortha Ave. and ends at Cedar Ave. and runs in the alley between Main St and Rose St, see Figure 8.

Summary					
Location	**Improvement**	**Approximate Length**	**Minimum Slope**	**Approximate Cover**	**Approximate Capacity**
		(ft)	(%)	(ft)	CFS
Alley, Dortha to Cedar	12’ x 8’ Precast Concrete Box	560’	1%	0.5’ - 1’	1,700 +/-
Notes: • Box storm drain size is anticipated to match the size of the Dortha box culvert crossing. The installation of a storm drain box would still allow for a shallow open channel above to capture localized drainage from the adjacent properties.					

Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**
Topography			
		This segment generally follows the alignment and slope of the existing open channel.	
Boundary/property/easement			
	Drainage easement	An existing 16’ public utility easement runs along the alley at the back sides of properties. The public utility easement is not intended for drainage.	The City of Flagstaff is obtaining additional drainage easements as part of the Dortha box culvert project.
Utilities			
	Gas main	UES owns a gas main in the alley/channel.	Mark and pothole gas main. Align drainage improvements to avoid gas main. Gas main may be relocated as part of the Dortha box culvert project.
	Overhead Power & Communication Lines	Construction of the box storm drain will conflict with overhead utilities and utility poles.	Relocate overhead power and communications lines underground.
	Dortha Box Culvert Crossing (Segment 7)	A new box culvert crossing Dortha Ave is currently being designed with an anticipated construction date of April 2022.	Match upstream invert of the Dortha box culvert, approximately 10’ below existing ground.
Structure/Building			
	Sheds	Several properties have sheds that abut the channel	Relocate sheds as necessary.

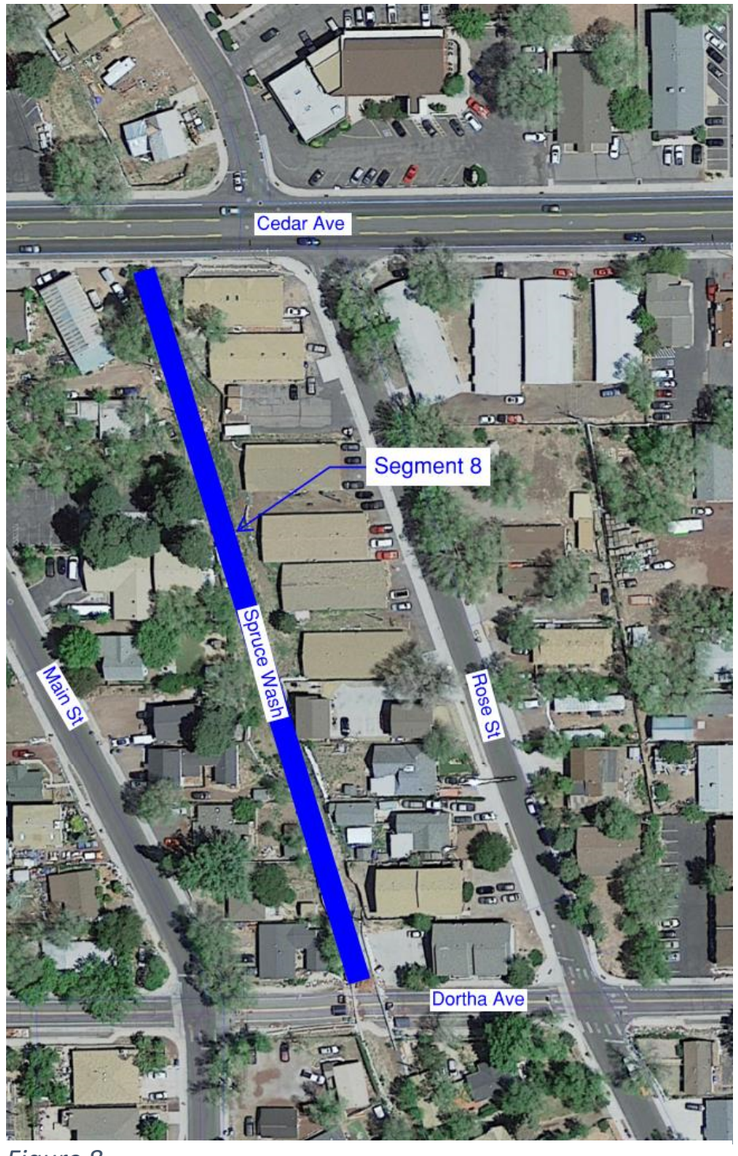

Figure 8

SEGMENT 9 – CEDAR AVE FROM ALLEY TO ALLEY

Segment 9 crosses Cedar Ave. from alley to alley, see Figure 9.

Summary					
Location	**Improvement**	**Length**	**Minimum Slope**	**Cover**	**Capacity**
		(ft)	(%)	(ft)	CFS
Cedar Ave.	12’ x 8’ Precast Concrete Box	95’	1%	5’	1,700 +/-
Notes: • The proposed box storm drain size matches the Dortha box culvert crossing size. • Segments 8 & 10 include open channels above the box storm drain allowing for conveyance of local runoff. A culvert under Cedar Avenue, above the box storm drain, will connect the channels. • A sewer main crossing in Cedar Ave. would need to be realigned to Main St.					

Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**
Topography			
		Maintain existing roadway profile on Cedar Ave.	
Boundary/property/easement			
		Work would be done in existing right of way.	
Utilities			
	Sewer Main	There is a crossing conflict with an existing 6” sewer main in Cedar Ave. There are 1-2 services connected to this section of sewer.	Realign sewer main to run west towards Main St.
	Gas Main	UES owns a gas main in the channel/alley	Mark and pothole gas main. Align drainage improvements to avoid gas main. Relocate gas main as necessary.
	Cedar Storm Drain	An existing storm drain under Cedar Ave enters the west side of Spruce Wash at the north edge of Cedar.	Maintain storm drain invert.
Structure/Building			
		There are no anticipated impacts.	

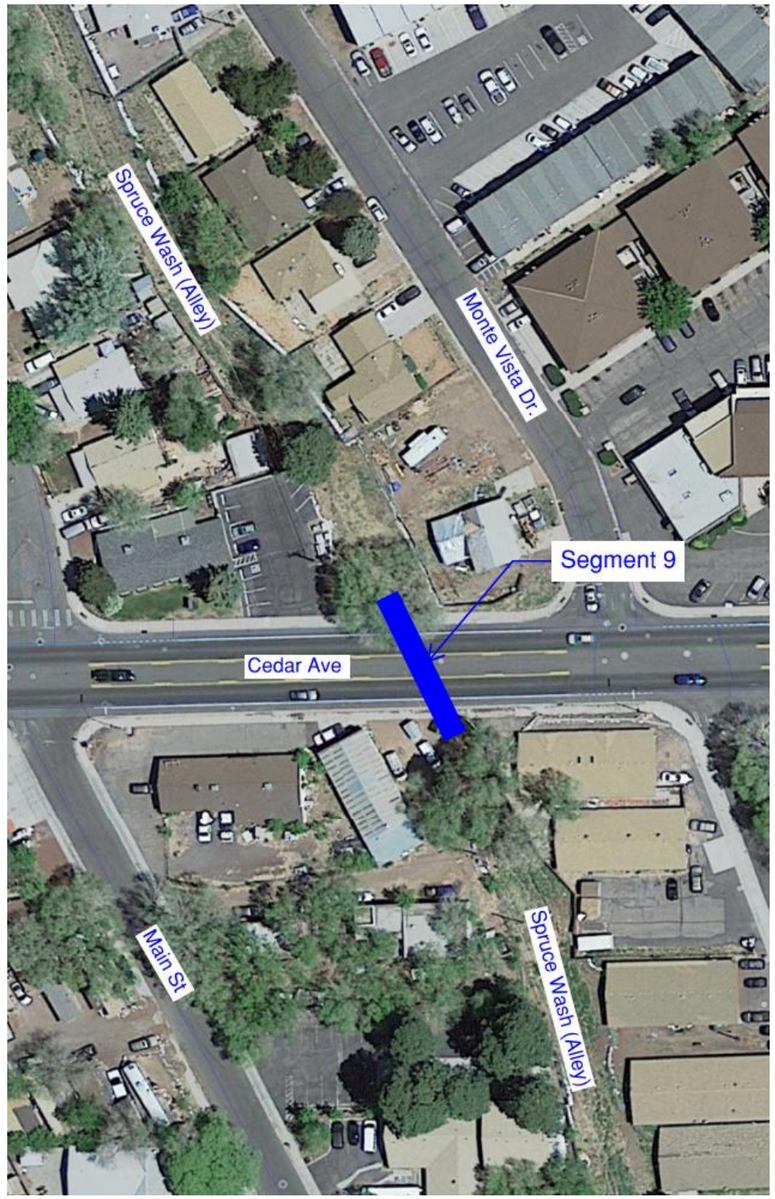

Figure 9

SEGMENT 10 – ALLEY FROM CEDAR TO LINDA VISTA

Segment 10 runs in the alley between Grand View Dr. and Monte Vista Dr., see Figure 10.

Summary					
Location	**Improvement**	**Length**	**Minimum Slope**	**Cover**	**Capacity**
		(ft)	(%)		CFS
Alley, Cedar to Linda Vista	12’ x 6’ Precast Concrete Box	2,260’	1.8%	Varies	1,500 +/-

Notes:

- The proposed box storm drain is set below the flowline of the existing channel which allows for an open channel above to capture localized drainage from the adjacent properties.
- Further field investigation of the channel north of Cedar Avenue concluded that the available space between existing fences is insufficient to fit the trapezoidal channel as proposed in the draft feasibility analysis. Rather than reduce the channel footprint The City directed that the channel be replaced with a box culvert.

Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**
Topography			
		This segment follows the general alignment and slope of the existing open channel.	
Boundary/property/easement			
	Drainage Easement	There is an existing variable width (~50’ – 80’) drainage easement along the channel.	Final design should include a boundary survey.
Utilities			
	Gas Main	UES owns a gas main along Spruce Wash.	Mark and pothole gas main. Align drainage improvements to avoid gas main. Relocate gas main as necessary.
	APS Utility Appurtenances	APS owns utilities in Spruce Wash.	Mark and pothole utilities. If unavoidable, relocate APS facilities.
	Overhead Power & Communication Lines	Construction of the channel may conflict with overhead utilities and utility poles.	Relocate overhead power and communications lines underground.
Structure/Building			
		There are no anticipated impacts.	

Figure 10

SEGMENT 11 – LINDA VISTA FROM ALLEY TO PARCEL 109-04-060 (WOLFF)

Segment 11 crosses Linda Vista from alley to Parcel 109-04-060 (Wolff), see Figure 11.

Summary					
Location	**Improvement**	**Length**	**Minimum Slope**	**Cover**	**Capacity**
		(ft)	(%)		CFS
Linda Vista	12’ x 6’ Precast Concrete Box	2,252	1.8%	Varies	1,500 +/-

Notes:

- Proposed box culvert extends approximately 60’ upstream of Linda Vista Dr.
- The proposed box storm drain is set below the flowline of the existing channel which allows for an open channel above to capture localized drainage from the adjacent properties.
- Segments 10 & 12 include open channels above the box storm drain allowing for conveyance of local runoff. A culvert under Linda Vista Drive, above the box storm drain, will connect the channels. A sewer main crossing in Linda Vista Dr will need to be realigned.

Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**
Topography			
		This segment follows the general alignment and slope of the existing open channel.	
Boundary/property/easement			
	Drainage Easement	The existing drainage easement width varies. The width of the drainage easement upstream of the box culvert is ~100’ wide. The width of the drainage easement downstream of the box culvert is ~75’ wide.	The proposed improvements should be contained within the existing easements.
Utilities			
	Sewer Main	There is a crossing conflict with an existing sewer manhole in Linda Vista Dr.	Remove the manhole and realign the sewer main to run between new manholes along the east side of Linda Vista Dr.
	Gas Main	UES owns a gas main that runs parallel to Spruce Wash	Align drainage improvements to avoid gas main or relocate if needed.
	Overhead Power & Communication Lines	Construction of the box culvert may conflict with overhead utilities and utility poles.	Relocate overhead power and communications lines underground.
Structure/Building			
None.			

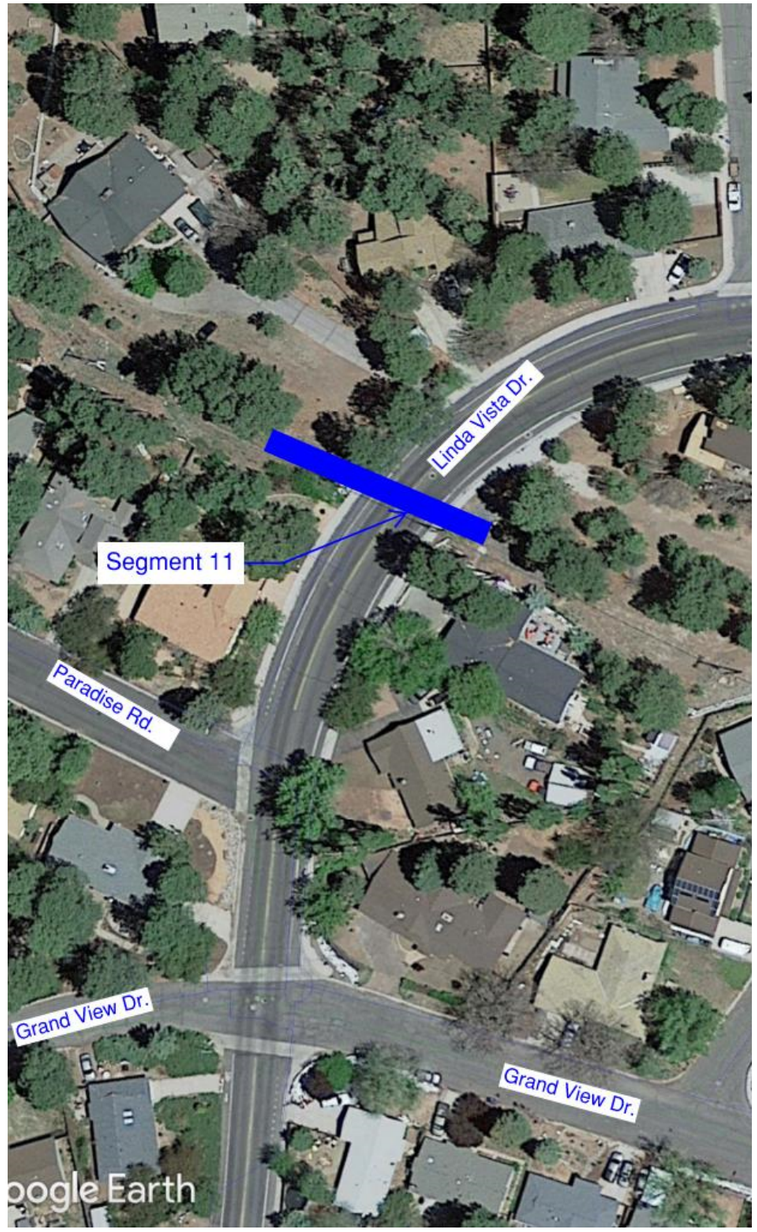

Figure 11

SEGMENT 12 – NORTH OF LINDA VISTA TRANSITION TO PARK WAY SEDIMENTATION BASINS

Segment 12 is north of Linda Vista Drive, see Figure 12.

Summary					
Location	**Improvement**	**Length**	**Minimum Slope**	**Cover**	**Capacity**
		(ft)	(%)		CFS
Linda Vista	Channel Transition	300’	1.5% - 5.5%	NA	Varies
Notes: • Natural Channel Design (NCD) provided concept plans for the Park Way sedimentation basins which show a 30’ wide open channel with 2:1 side slopes downstream of the last basin. The channel would then transition and deepen over a 100’ section to a 12’ wide by 4.5’ deep concrete trapezoidal channel with 2:1 side slopes and then transition again in a 100-ft section to a rectangular channel with a 12’ bottom width, 8-ft deep. The 12’x8’ rectangular channel terminates at the proposed box culvert at Linda Vista (Segment 11).					

Constraints & Conflicts			
	Description	**Design Considerations**	**Comments**
Topography			
		Transition channel within the footprint of the proposed 30’ channel that is part of the Park Way basin improvements.	
Boundary/property/easement			
	Drainage Easement	The existing drainage easement width varies. The width of the drainage easement upstream of the box culvert is ~100’ wide.	The proposed improvements should be contained within the existing easements.
Utilities			
	Gas Main	UES owns a gas main that runs parallel to Spruce Wash	Align drainage improvements to avoid gas main and relocate if needed.
	Overhead Power & Communication Lines	Construction of the channel transitions may require relocation of overhead utilities and utility poles.	Relocate overhead power and communications lines underground.
Structure/Building			
		Avoid existing structures along the channel.	

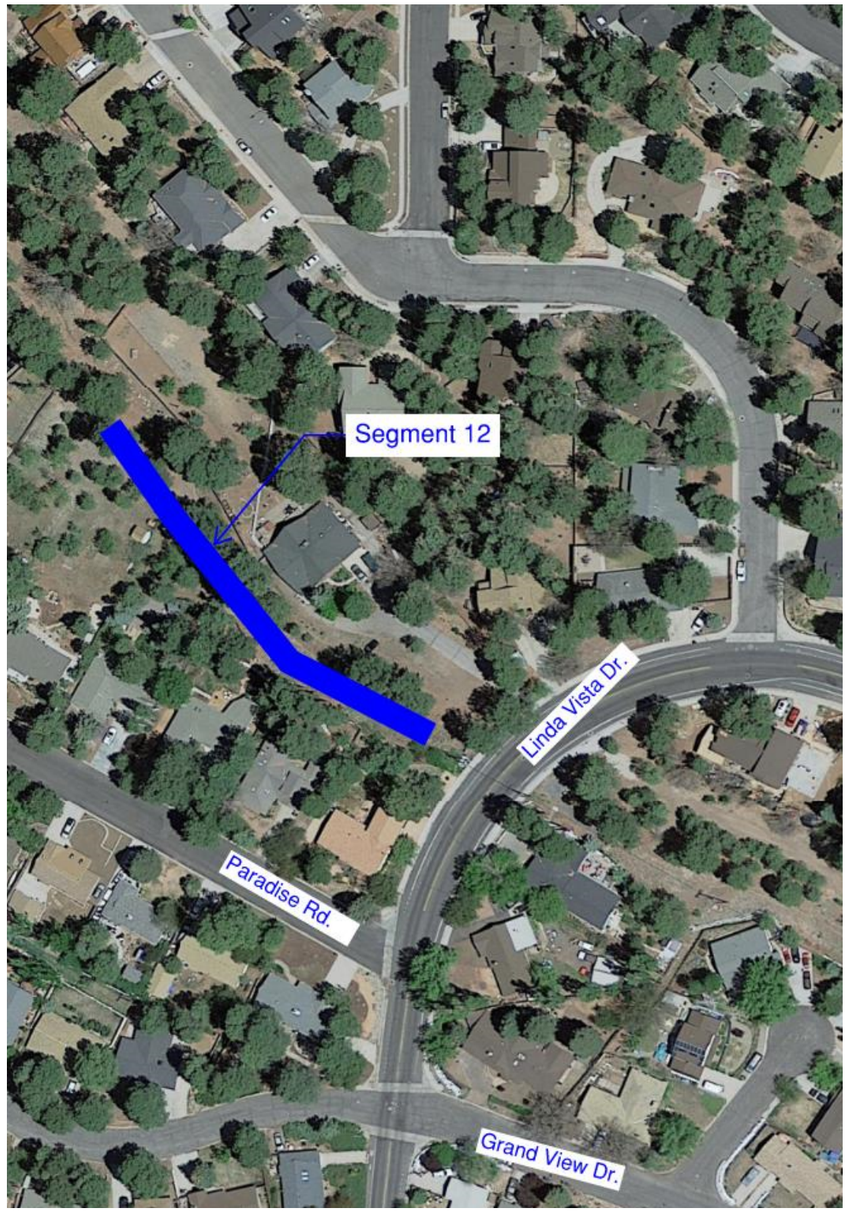

Figure 12