John Wesley Powell Blvd Extension - East

RAINBOW ROAD ENGINEERING

LETS-A-GO

CENE486C Final Presentation
May 3rd, 2024

CITY ENGINEERING DIVISION
CITY OF FLAGSTAFF

Rainbow Road Engineering

“Let's-A-Go”

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Project Background

Project Purpose

- Design approximately 2.5 mile road extension to existing JWP Blvd
- Additional arterial to network
- Aids future development

Client

- City of Flagstaff & Metroplan Flagstaff

Technical Advisor

- Nathan Reisner & Edward Smaglik

Location

- Western terminus north of Pine Canyon subdivision
- Connect with Fourth Street intersection on east side of town

Project Area

- Rio de Flag & Arizona Trail
- Multiple landowners in area

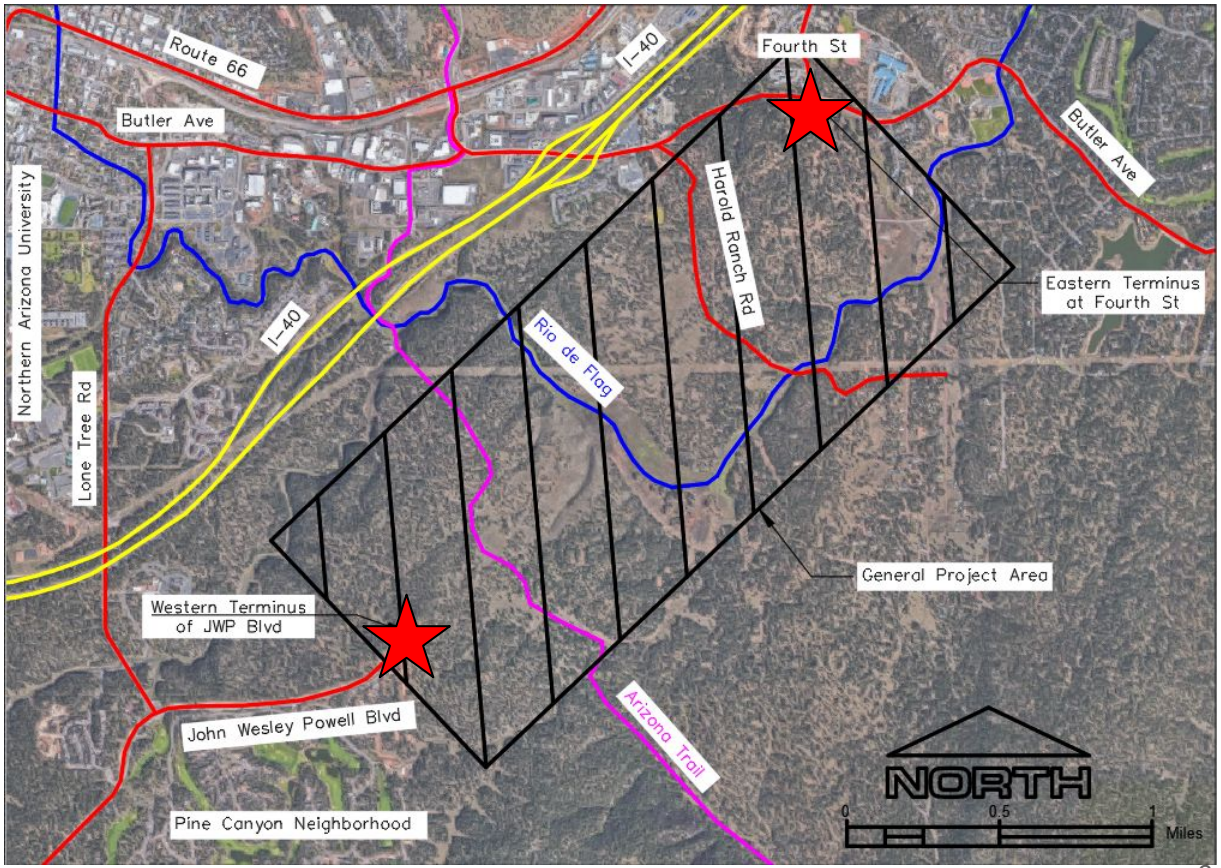


Figure 1, Project Location within Flagstaff [2]

Figure 2, East Terminus Culverts
Credit: James H

Figure 3, East Terminus Sidewalk
Credit: James H

Figure 4, East Terminus Cross Section
Credit: James H

Figure 5, East Terminus Retention Basin
Credit: James H

Existing Conditions Eastern Terminus

- Ignoring construction/development
- Butler Ave and Fourth St intersection to be redesigned
- No Topography/GIS for new construction

Figure 6, West Terminus Undeveloped Site
Credit: James H

Figure 7, West Terminus Road
Credit: James H

Figure 8, West Terminus View of East 1
Credit: James H

Figure 9, Western Terminus View of East 2
Credit: James H

Existing Conditions Western Terminus

- The Western Terminus is coned off from public access
- No further development
  - Leveled off land
  - Drainage
  - Culverts

Major Roadway Considerations

- Extension must cross Rio de Flag
- Intersection design with Herold Ranch Rd
- Adjustments to Arizona Trail

Figure 10, Rio de Flag Looking West at Herold Ranch Rd
Credit: Owen Allen

Figure 11, Herold Ranch Rd Looking North at Rio de Flag
Credit: Owen Allen

Figure 12, Arizona Trail Looking North
Credit: Owen Allen

Preliminary Traffic Assessment - 2045 Traffic Projections

Equation 1, Directional Peak Hour Volume

$$DPHV = AADT * K * D$$

DPHV - Directional Peak Hour Volume (veh/hr)
AADT - Average Annual Daily Traffic (veh/day)
K - K-Factor: Percentage of AADT in an hour
D - D-Factor: Directional traffic volume ratio

Table 1, Road Segment Peak Hour Volume Calculations

PHV Calculations	Segment		
	West End	Middle	East End
AB Flow	7656	5644	8274
BA Flow	8437	5604	6970
Total Flow	16093	11248	15245
K-Factor	0.10	0.10	0.10
D-Factor	0.52	0.50	0.54
AB PHV	401	283	449
BA PHV	442	281	378

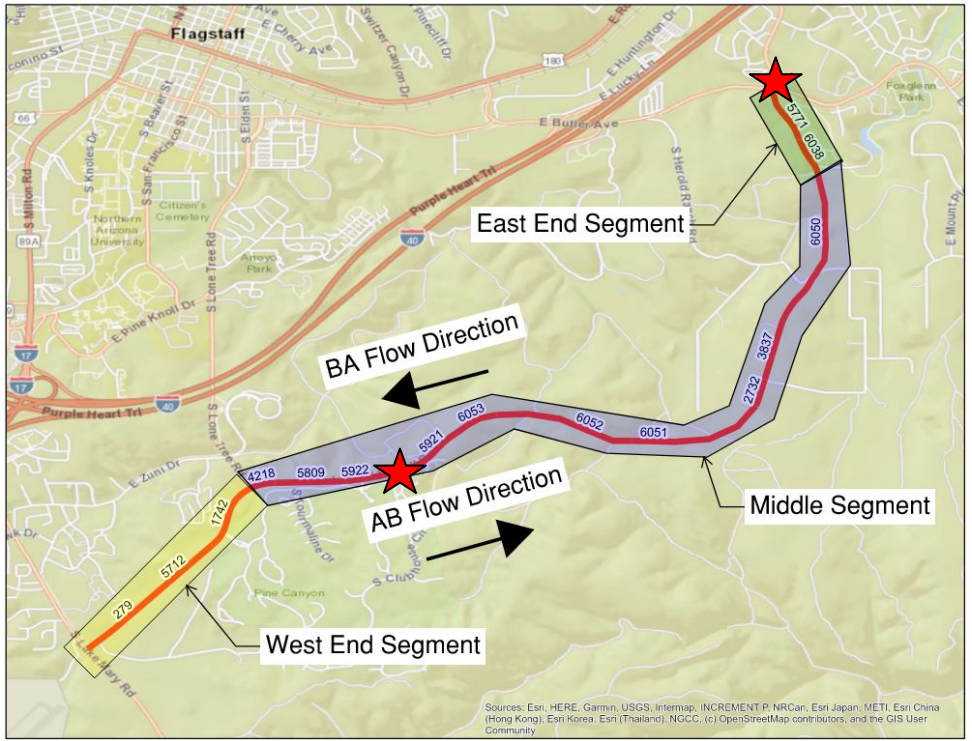


Figure 13, Network Volumes Segment ID Map

Road Segment Analysis - 2045 Traffic Projections

Table 2, LOS Calculations for Two Lane Highway

LOS Calculations for Two Lane Highway			Segment		
			West End	Middle	East End
Road Type	Arterial	ATSd	30.1	23.5	30.5
Road Class	III	PFFSd	75.3	78.4	76.2
LOS			C	C	C

*All calculations were done using Chapter 15 of the HCM 2010

LOS	Class I Highways ATS (mi/h)	Class I Highways PTSF (%)	Class II Highways PTSF (%)	Class III Highways PFFS (%)
A	>55	≤35	≤40	>91.7
B	>50–55	>35–50	>40–55	>83.3–91.7
C	>45–50	>50–65	>55–70	>75.0–83.3
D	>40–45	>65–80	>70–85	>66.7–75.0
E	≤40	>80	>85	≤66.7

Figure 14, Automobile LOS for Two-Lane Highways

Fourth St

Intersection Analysis - 2045 Traffic Projections

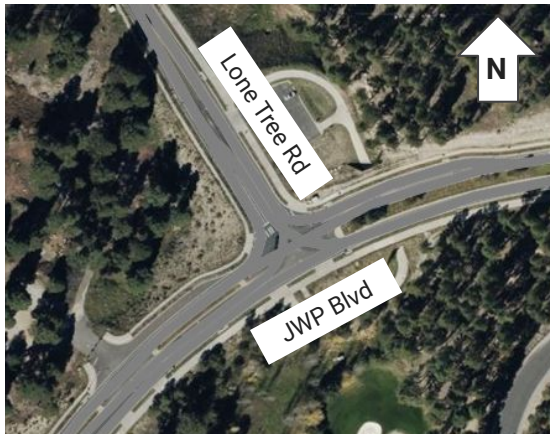


Figure 15, JWP Blvd & Lone Tree Rd Intersection

Figure 16, JWP Blvd & Herold Ranch Rd Intersection

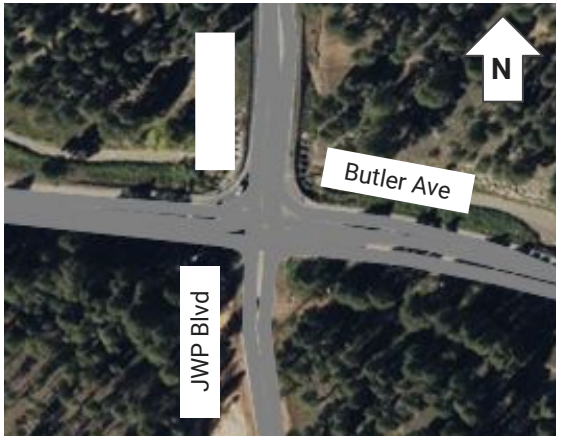


Figure 17, JWP Blvd at Butler Ave & Fourth St Intersection

Table 3, Intersection Level of Service Determined from Vissim

Intersection Level of Service Determined from Vissim	
Intersection	Level of Service
Lone Tree Intersection	A
Herold Ranch Intersection	A
Butler and Fourth Intersection	C

Preliminary Hydrologic Analysis

Identification of Watersheds and Determination of Peak Flows

- Delineate Watersheds
  - City of Flagstaff GIS Natural Environment data
  - Rio de Flag
  - Pine Canyon Wash.
  - 100-year flow rate
  - Rio de Flag FEMA study

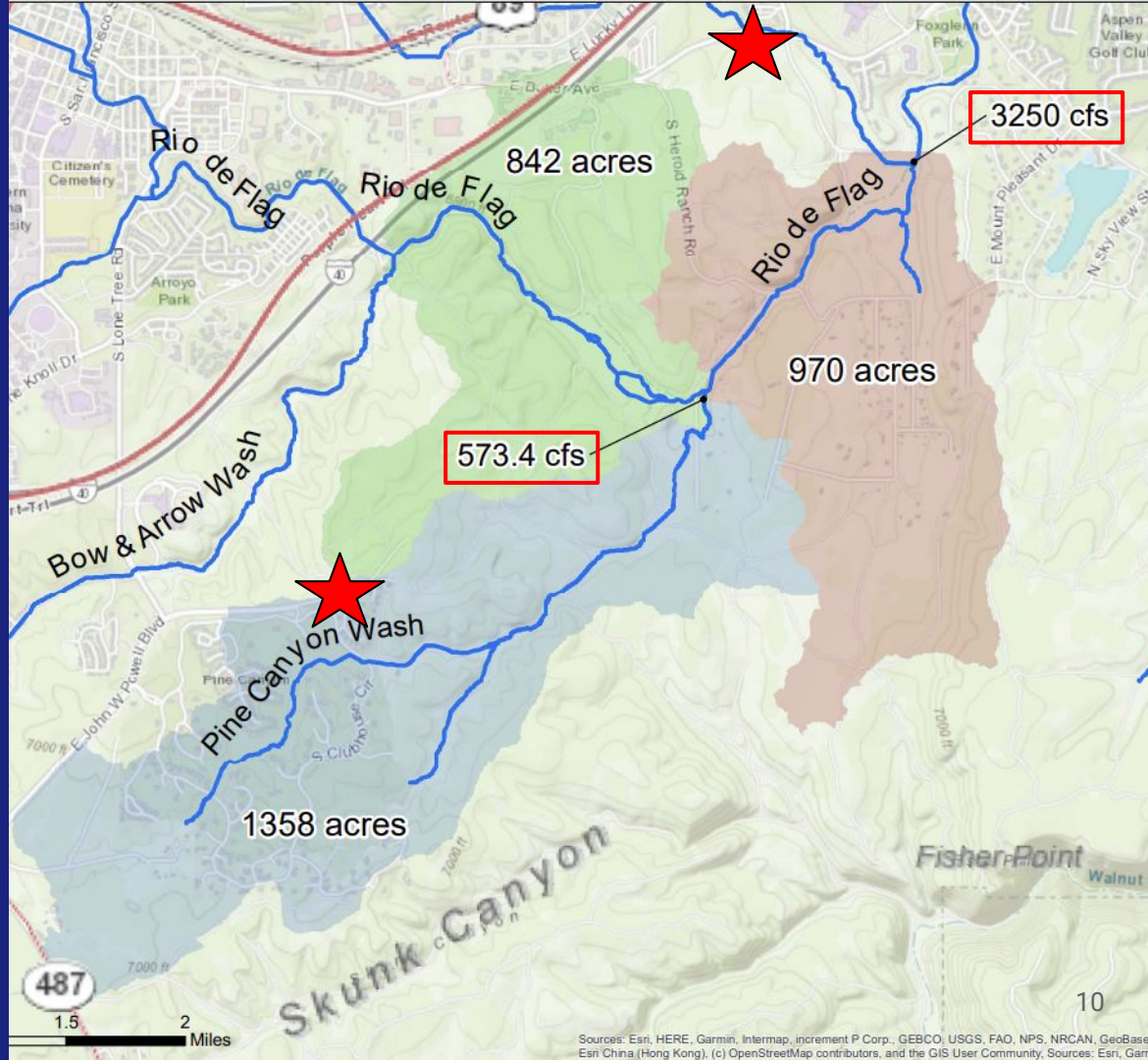


Figure 18, JWP- Watershed Map Data [11]

Preliminary Hydraulic Analysis Cont.

- SCS TR-55 Method
  - Unit peak discharge of watershed, watershed area, runoff, and pond/swamp correction factor.
  - Unit peak discharge related to time of concentration.
- Peak discharge of 573.4 cfs from Pine Canyon Wash.

Equation 2, Peak Discharge [11]

$$q_p = q_u A_m Q F_p$$

q_p - Peak discharge of watershed
q_u - Unit peak discharge
A_m - Area of watershed
Q - Runoff

Table 4, Peak Flow Values

100-Year Peak Discharge (cfs)	Unit peak discharge (csm/in)	Area of watershed (mi^2)	Runoff (in)	Pond/Swamp Adjustment Factor	100-year 24-hour Rainfall (in)	Potential maximum retention (in)
573.4	140.0	2.12	2.10	0.92	4.56	3.33

Figure 19, Rio de Flag in Project Area

Roadway Design

- Base Map Development
  - Topo/GIS
  - Parcels defined
  - Existing utilities
- Determining Alignment
  - Alignment criteria
  - Alignment decision matrix
  - Horizontal and vertical curve design

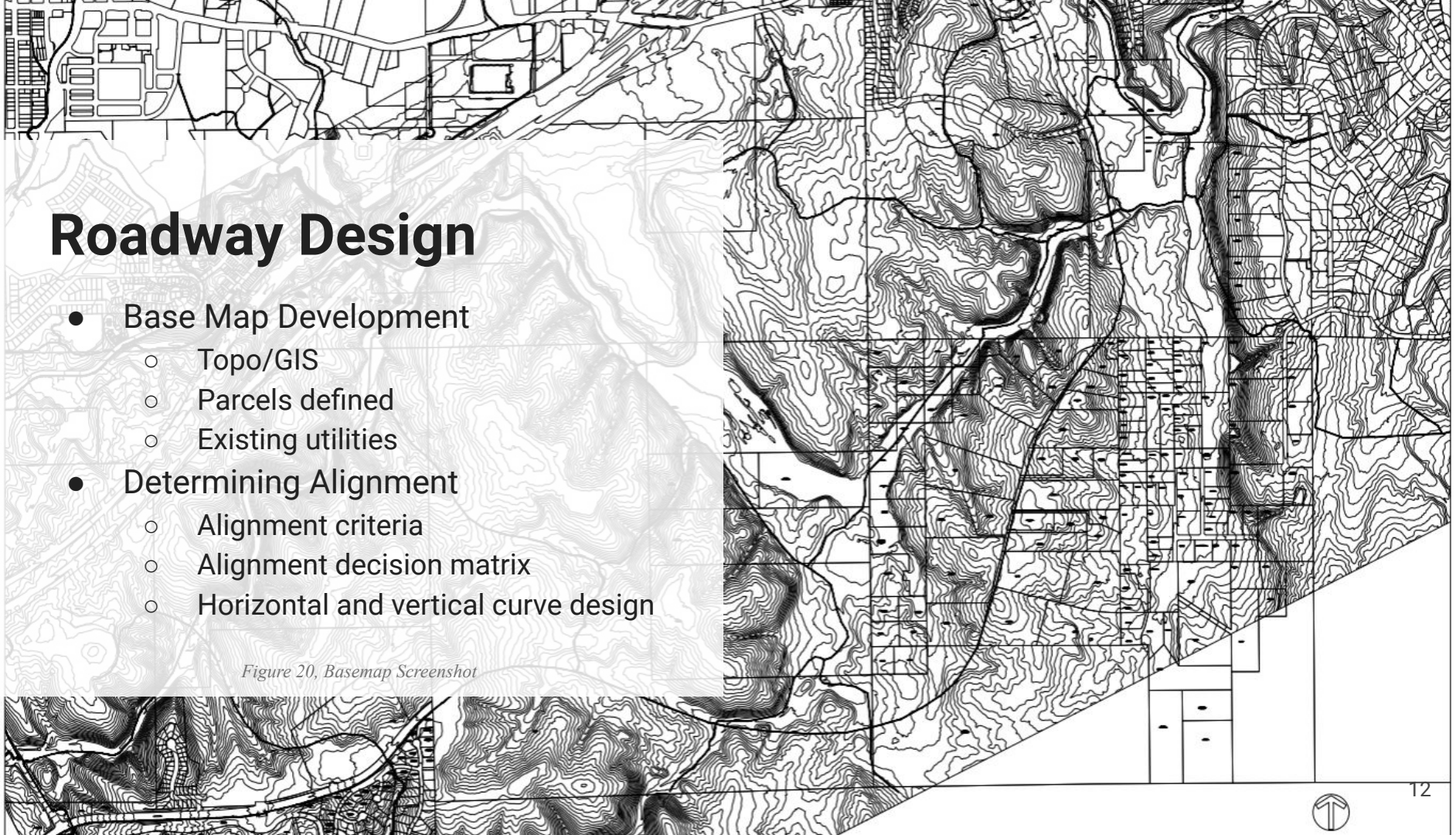


Figure 20, Basemap Screenshot

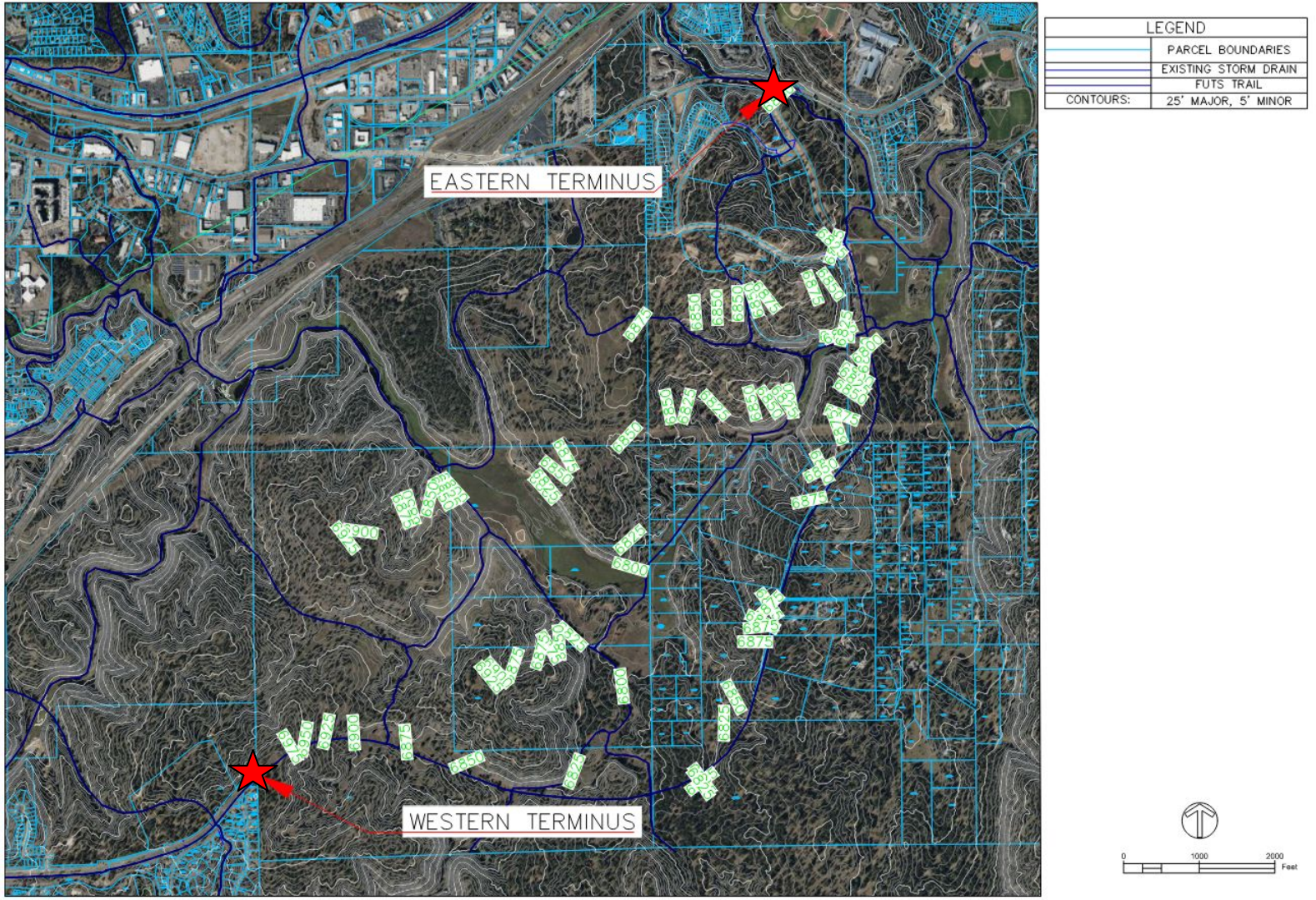


Figure 21, Basemap

Figure 22, Alignment Alternatives

Alignment Decision Matrix Criteria and Scoring

Table 5, Alignment Decision Matrix Criteria

Alignment Criteria		
Criteria	% Weight	Description
Existing Terrain	30	Topography will be assessed for least cut/fill
Environmental Impacts	5	Least amount of demolition to existing foliage
Hydraulic Considerations/Impacts	20	Number of crossings/ease of design
Roadway Length	30	Shortest roadway for longterm operational expenses
Property Aquisition	10	Least amount of private property impacted
User Comfort	5	Least amount of horizontal and vertical curves
Weighted Value Totals	100	

Table 6, Alignment Decision Matrix Scoring

Alignment Scoring					
Criteria	1	2	3	4	5
Existing Terrain	Just Fill	Just Cut	More Cut than Fill	More Fill than Cut	Equal Cut/Fill
Environmental Impacts	20,000<x<17,500 trees	17,500<x<15,000 trees	15,000<x<12,500 trees	12,500<x<10000 trees	<10,000 trees
Hydraulic Considerations/Impacts	5 Water Crossings	4 Water Crossings	3 Water Crossings	2 Water Crossings	1 Water Crossings
Roadway Length	4<x<4.5 mi	3.5<x<4 mi	3<x<3.5 mi	2.5<x<3 mi	<2.5 mi
Property Aquisition	Splits major and large parcels	Splits Major and Small parcels	Splits Minor and Big parcels	Minor and small splits	Doesn't split parcels
User Comfort	Sharp Curves, require speed limit decrease	Inconvenient alignment path, Sharp curves	Inconvenient alignment path, Smooth curves	Smooth curves	Least amount of curves

Alignment Decision Matrix

Table 7, Alignment Decision Matrix

Potential Alignments		Red Alignment		Yellow Alignment		Blue Alignment	
Criteria	% Weight	Value	Weighted Value	Value	Weighted Value	Value	Weighted Value
Existing Terrain	30	4	1.2	1	0.3	3	0.9
Environmental Impacts	5	3	0.15	1	0.05	4	0.2
Hydraulic Considerations/Impacts	20	3	0.6	1	0.2	4	0.8
Roadway Length	30	3	0.9	5	1.5	2	0.6
Property Acquisition	10	5	0.5	2	0.2	1	0.1
User Comfort	5	4	0.2	5	0.25	2	0.1
Weighted Value Totals	100		3.55		2.5		2.7

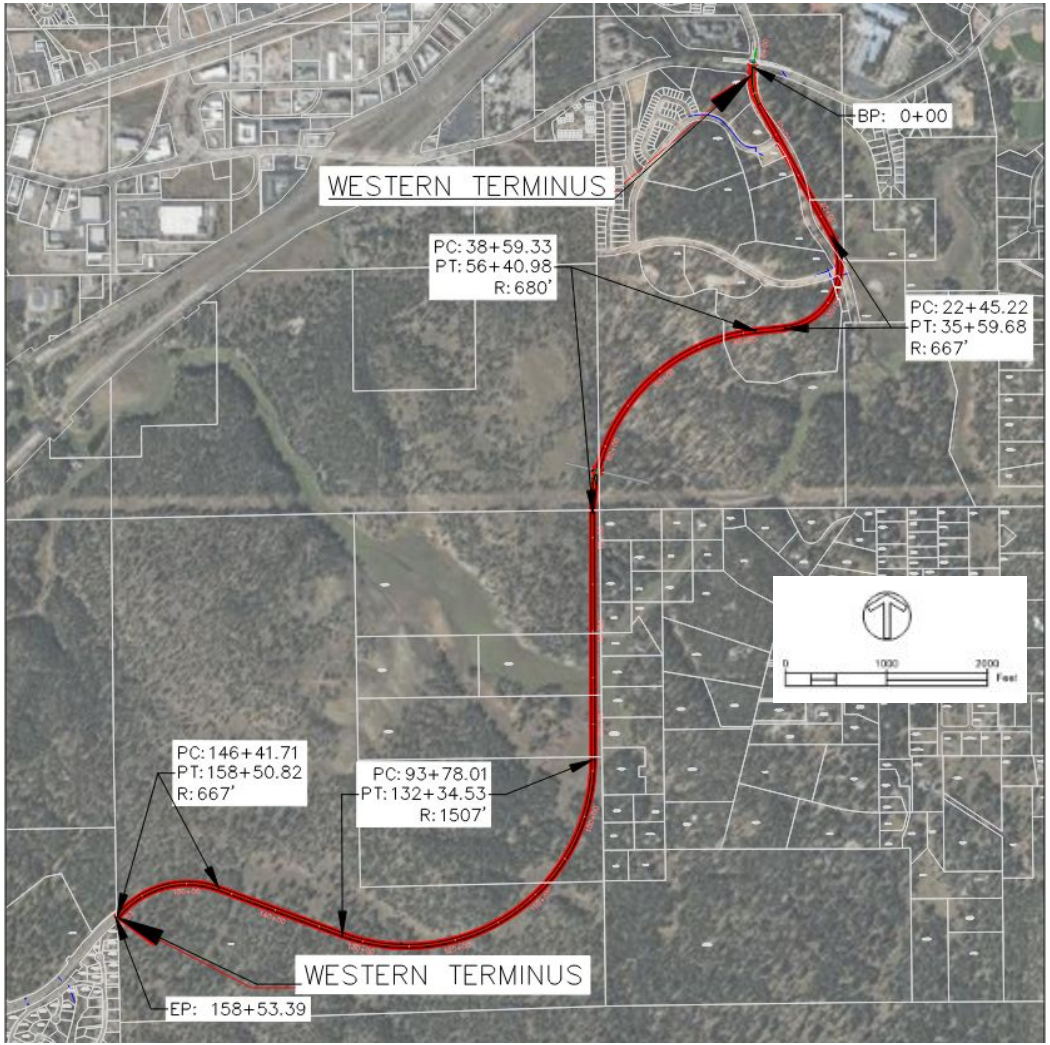


Figure 23, Horizontal Curve Radii on Alignment

Vertical Curve Design

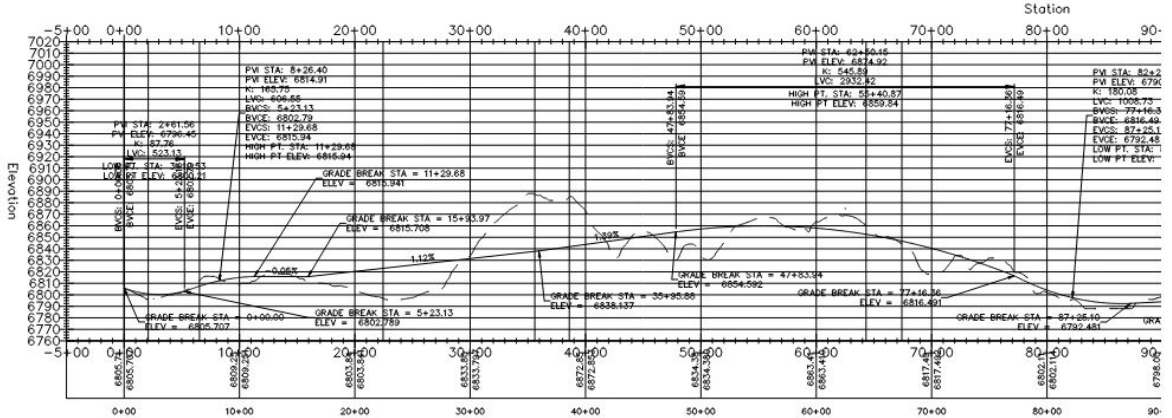


Figure 24, Alignment Vertical Curve Left

- Minimum Curve Length: 120’
- Minimum Rate of Vertical Curvature:
  - 44% Crest
  - 64% Sag

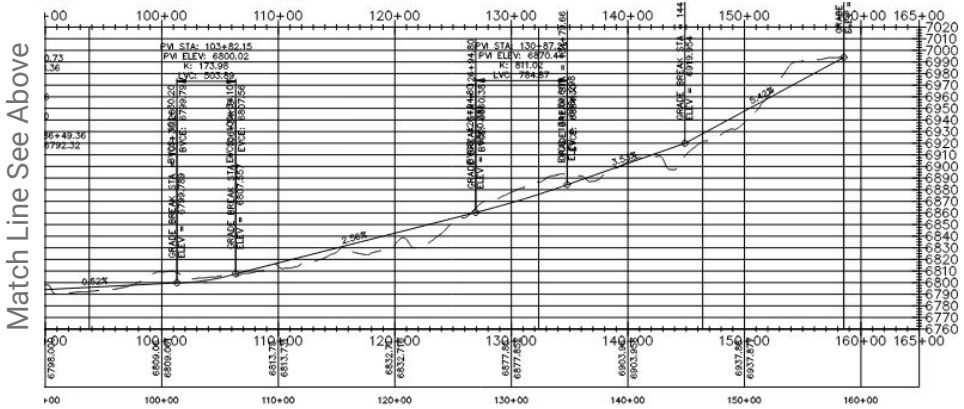


Figure 25, Alignment Vertical Curve Right

Roadway Cross-Section

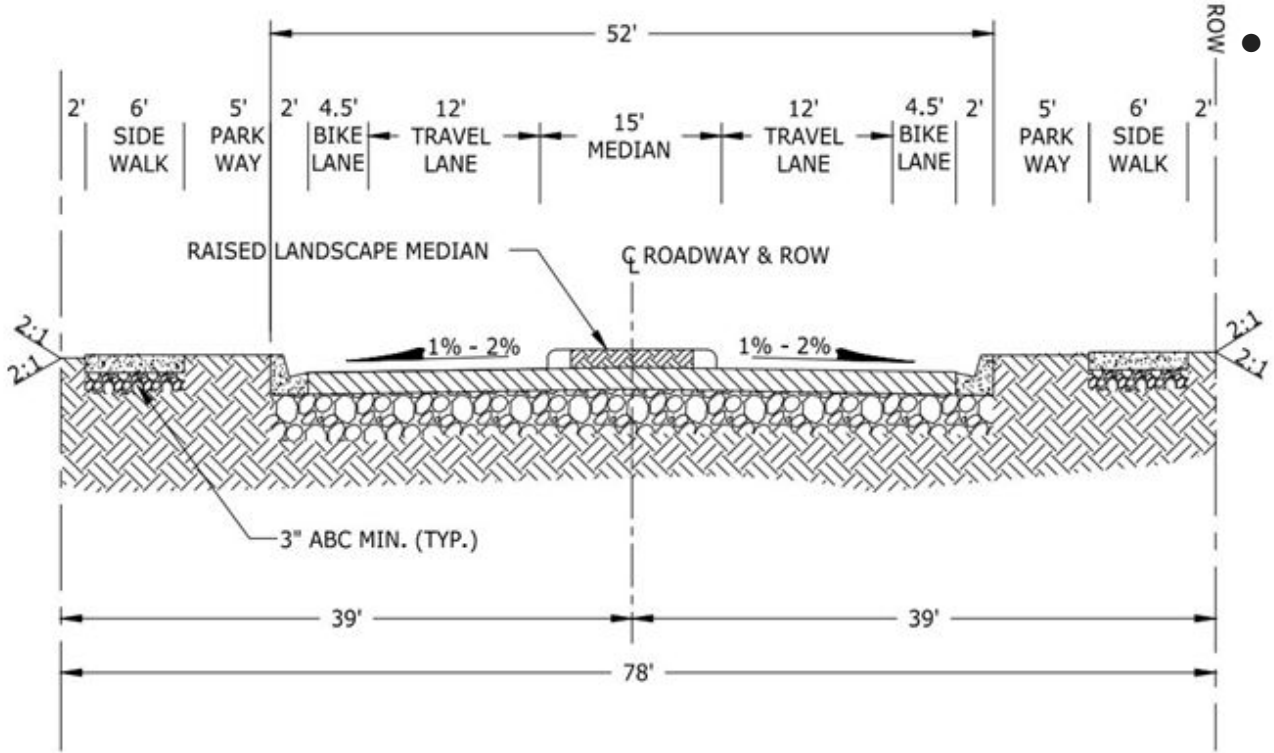


Figure 26, Minor Arterial Cross Section for JWP []

- Followed City of Flagstaff standard requirements
  - 6’ wide sidewalks
  - 5’ wide parkways
  - 2’ curb & gutter
  - 4.5’ wide bike lane
  - 12’ wide travel lanes
    - One in each direction
  - 15’ wide median

Signal/Intersection Design

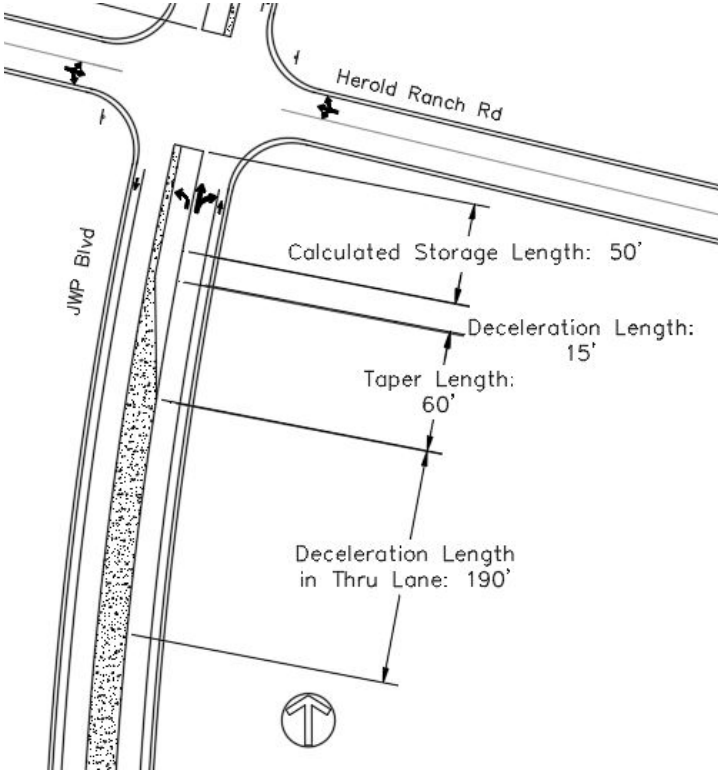
JWP Blvd & Herold Ranch Rd Intersection

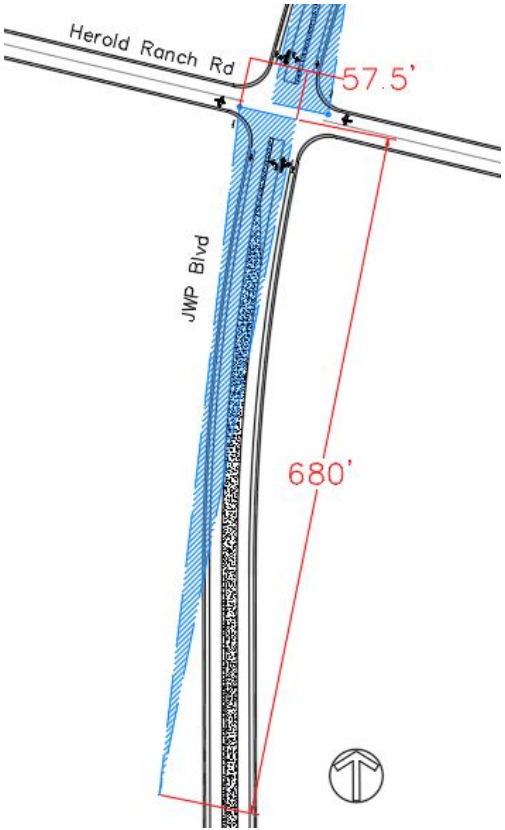
- Full geometric design
  - Realignment
  - Stop Control
  - Turning Lanes
    - Storage Lane Length
  - Intersection Sight Distance

Butler Ave & Fourth St Intersection

- S Leg JWP Blvd design
  - Turning Lanes
    - Storage Lane Length
  - Intersection Sight Distance
- Signal controller
  - Phasing

Herold Ranch Rd & JWP Blvd Intersection





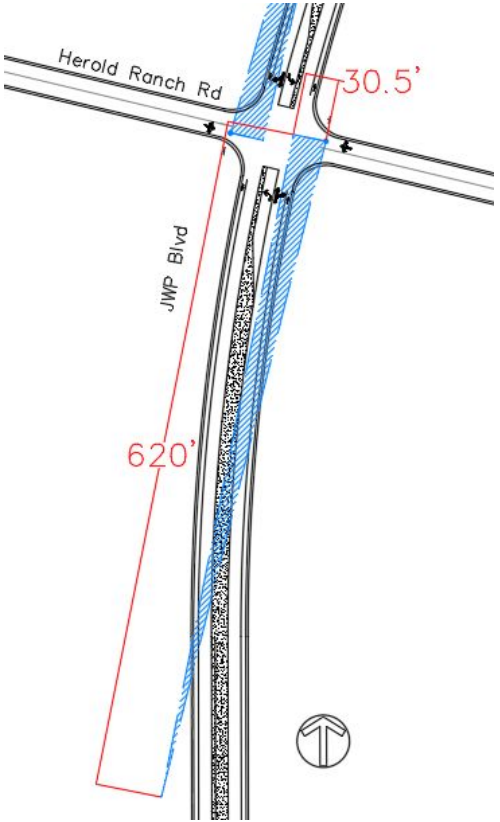


Figure 27, JWP Blvd & Herold Ranch Rd Storage Lane Dimensions

Figure 28, JWP Blvd & Herold Ranch Rd Right Sight Triangle

Figure 29, JWP Blvd & Herold Ranch Rd Left Sight Triangle

Butler Ave & Fourth St Intersection

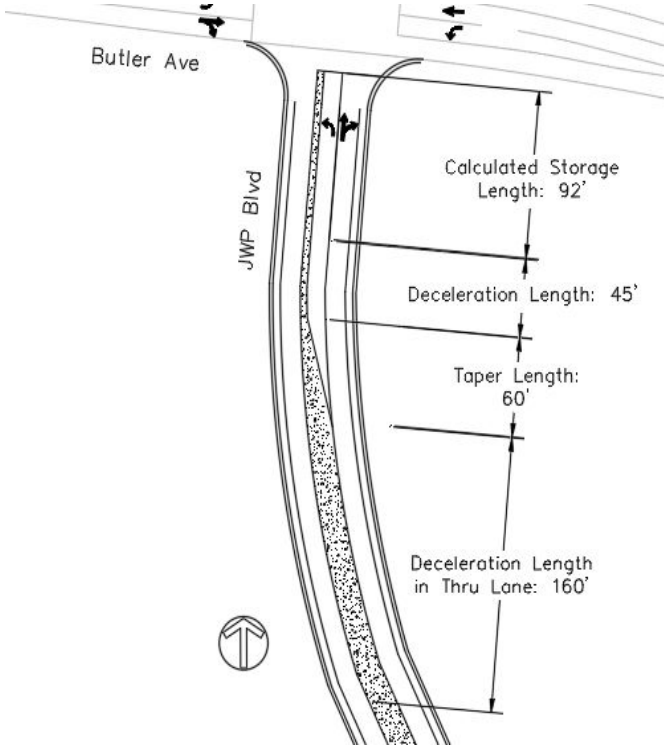


Figure 30, Butler Ave & Fourth St Storage Lane Dimensions

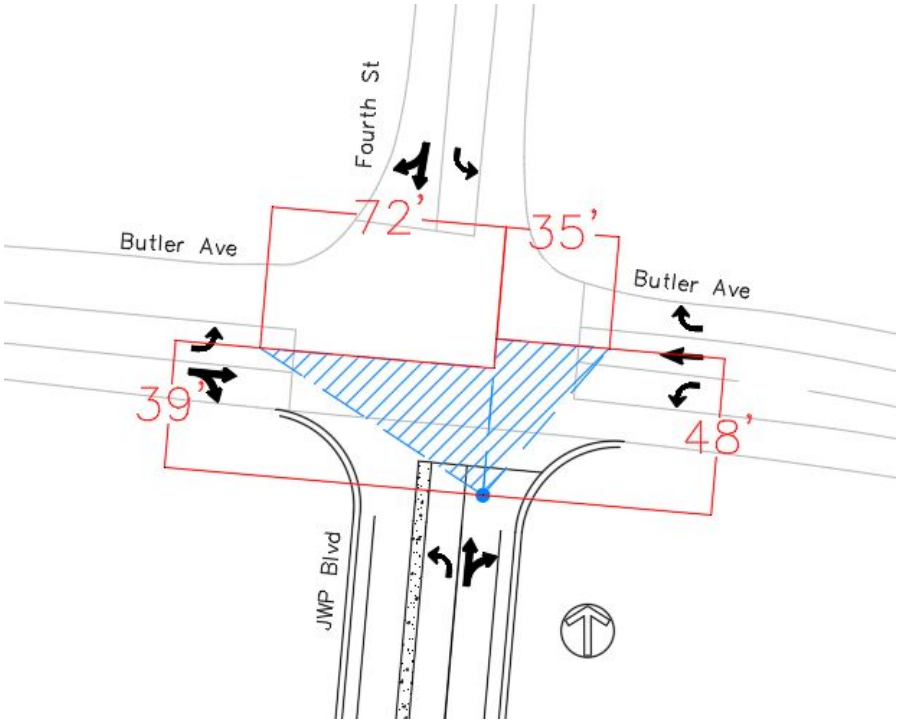


Figure 31, Butler Ave & Fourth St Sight Distance Triangles

Signage & Striping Plan

- Striping Plan
  - 6” white stripe
    - Bike lane
    - Turn lane
  - Left turn lane arrows
- Signage
  - After major geometric changes
    - Harold Ranch Rd
    - Butler Ave & Fourth St
  - Stop Sign
    - Harold Ranch Rd

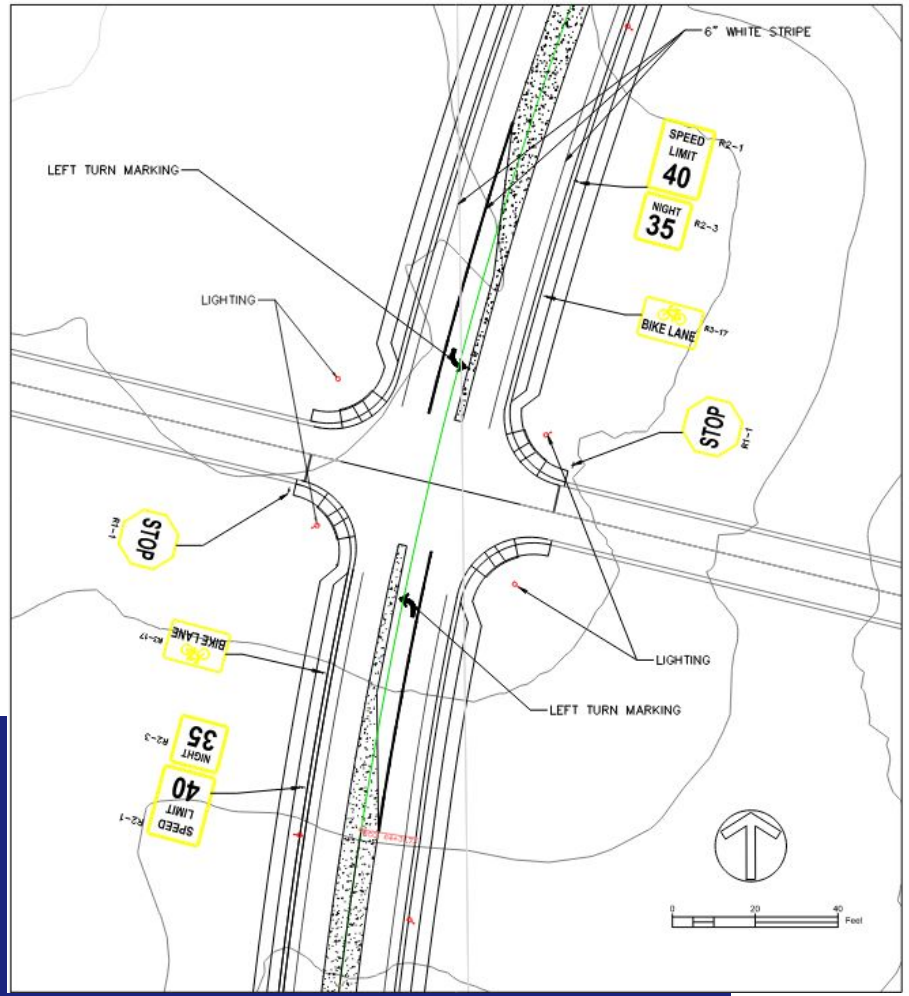


Figure 32, Signage and Striping

Lighting Plan

- Lighting every 200 ft
  - More lights then necessary
    - Urban, 250 ft
    - Rural, 200 ft
      - One side only
  - Both sides of roadway
  - COF Standard light poles
- Intersection
  - Lights on every corner
    - Harold Ranch Rd.

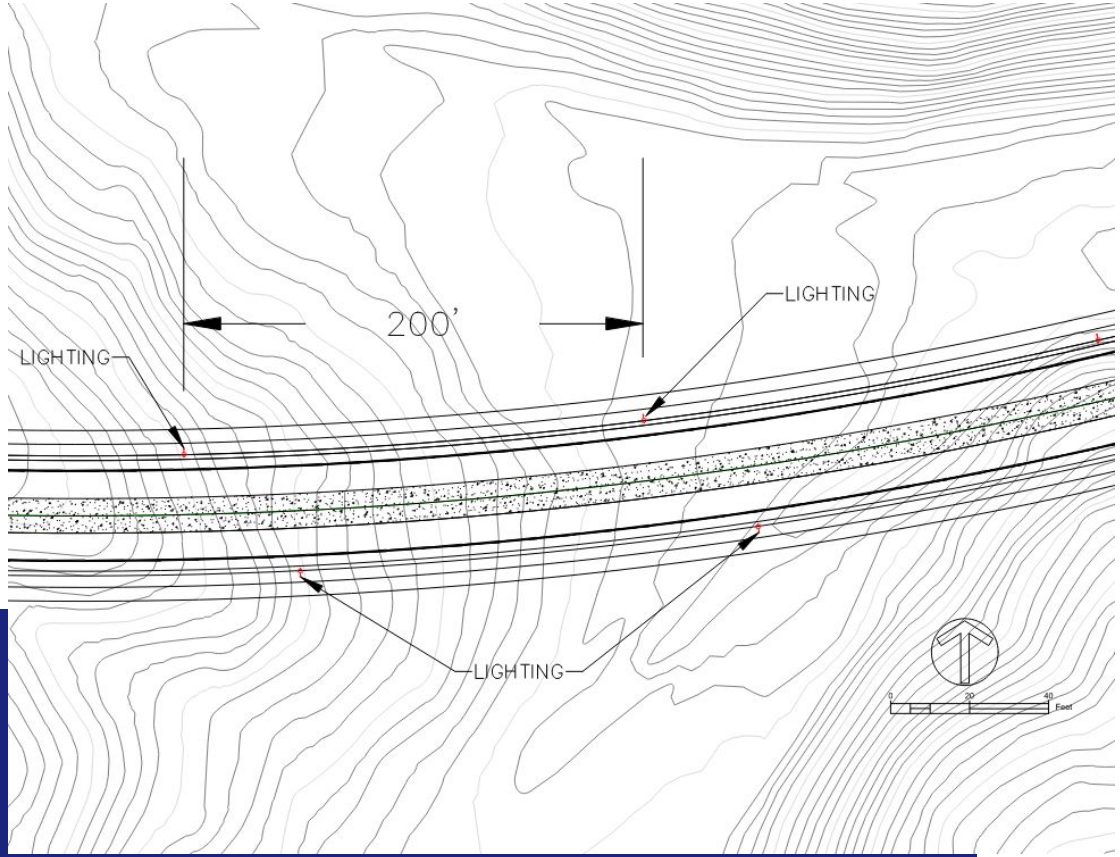


Figure 33, Lighting Plan

Wildlife Mitigation Considerations

- Movement Map
  - Green dots - Elk
  - Purple Line - Movement
- Crossing Map
  - Red is the highest amount of crossing per 1/10
  - 11-23 highest crossing
- Mitigation ideas
  - Impermanent
    - Signage
    - Speed limit reduction
    - Fence
  - Additional lighting
    - Lighting plan meets criteria

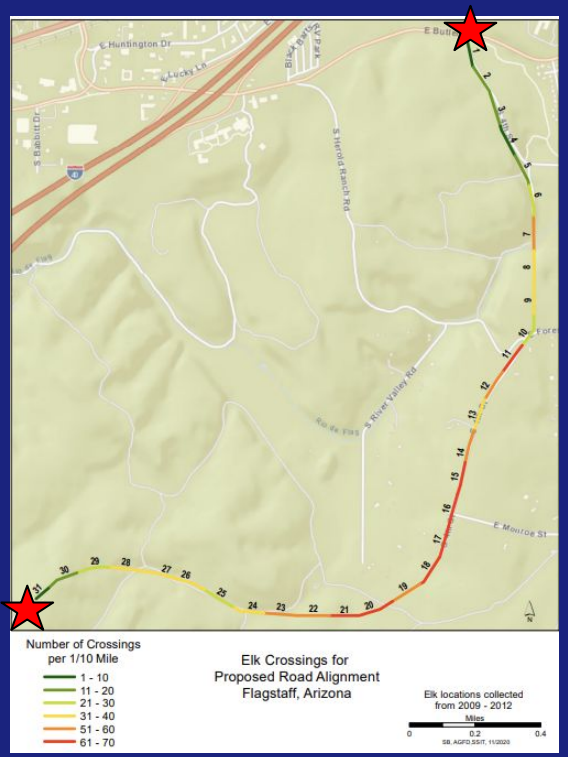


Figure 34, Elk Crossing Map [24]

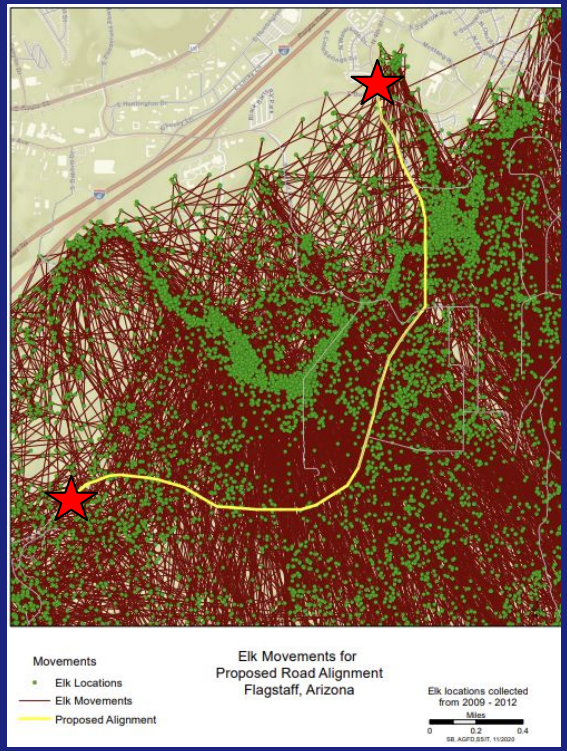


Figure 35, Elk Movements Map [23]

Wildlife Mitigation Plan for JWP

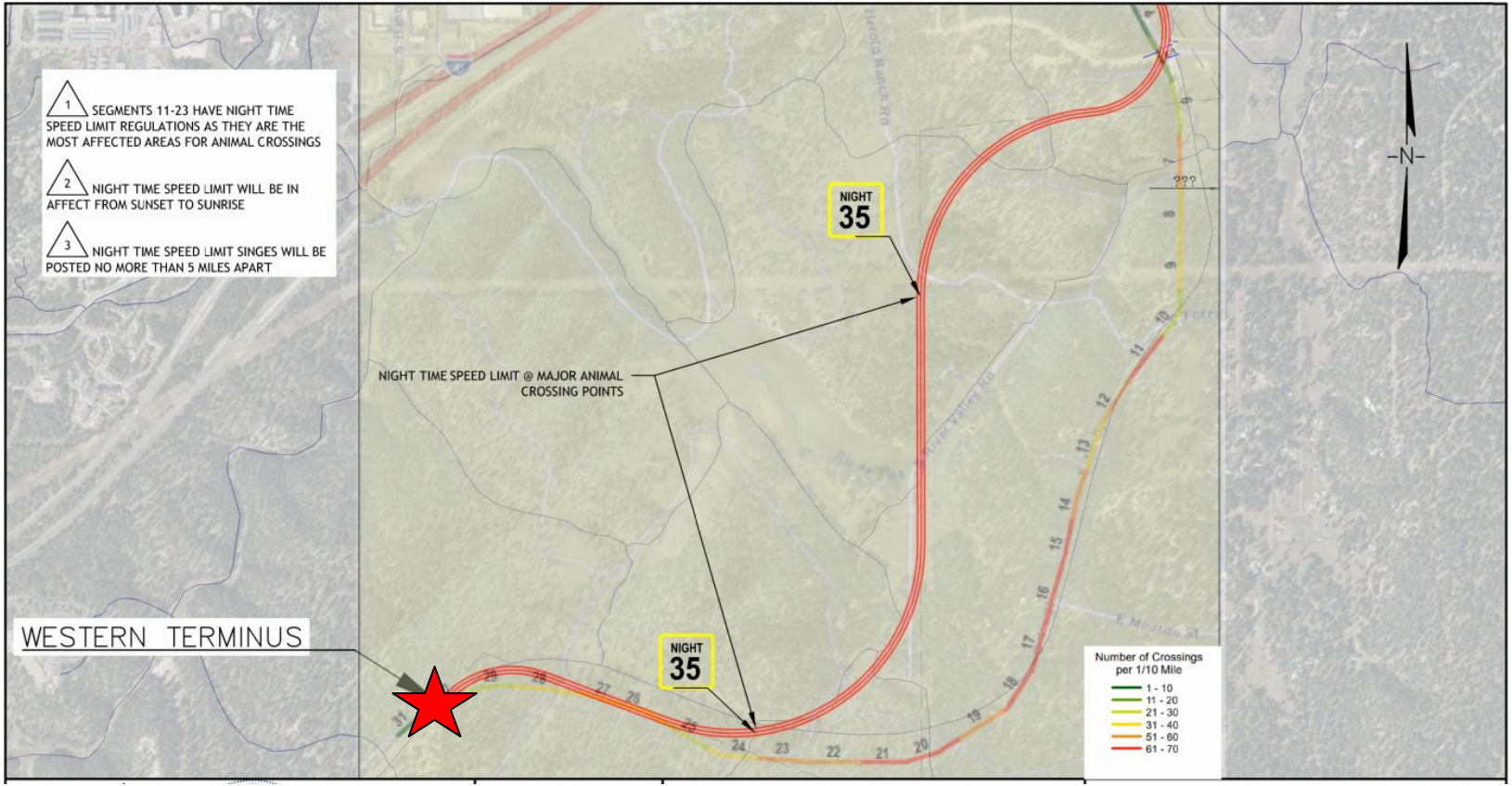


Figure 36, JWP Proposed Wildlife Mitigation Plan [24]

Post-Design Hydraulic Analysis/Design

Table 8, Water Crossing Criteria

Hydraulic Structure Criteria		
Criteria	% Weight	Description
Cost	30	Structure material cost, number of sections, prefabrication ability
Velocity	25	Outlet velocity of water
Headwater Elevation	25	Elevation of water at the inlet
Required Outlet/Inlet Protection	10	Required protection of the culvert inlet/outlet due to velocity
Aesthetic Apperance	10	Overall aesthetic apperance of the culvert

Table 9, Water Crossing Scoring

Water Crossing Matrix Scoring					
Criteria	1	2	3	4	5
Cost	No available prefabricated sections	Uncommon prefabricated sections, expensive material	Uncommon prefabricated sections, cheap material	Prefabricated sections available, expensive material	Prefabricated sections available, cheap material
Velocity	< 15 feet per second	12 - 15 feet per second	10 - 12 feet per second	4 - 10 feet per second	> 4 feet per second
Headwater Elevation	> 10.0 ft	10.0 ft - 8.0 ft	8.0 ft - 7.0 ft	7.0 ft - 6.0 ft	< 6.0 ft
Required Outlet/Inlet Protection	Velocity too high for design per COF	Wired tied riprap, energy dissipators	Wire tied riprap	Dumped riprap	No outlet protection
Aesthetic Apperance	Unaesthetically pleasing	Slightly aesthetically pleasing	Aesthetically pleasing	Moderatly aesthetically pleasing	Most aesthetically pleasing

- Two crossings, Rio de Flag & Pine Canyon Wash
- Decision matrix used to decide between three types of culverts.
- Cost, velocity, headwater elevation, required protection, and aesthetics were matrices criteria.
  - 5 considered best, 1 considered worst
- Qualitative and quantitative justification

Post-Design Hydraulic Analysis/Design - Rio de Flag

Table 10, Rio de Flag Crossing Decision Matrix

Rio de Flag - Water Crossing Type		Concrete Box		CMP Pipe		Arch Culvert	
Criteria	% Weight	Value	Weighted Value	Value	Weighted Value	Value	Weighted Value
Cost	30	4	1.20	5	1.50	3	0.90
Velocity	25	3	0.75	4	1.00	4	1.00
Headwater Elevation	25	5	1.25	5	1.25	4	1.00
Required Outlet/Inlet Protection	10	3	0.30	4	0.40	3	0.30
Aesthetic Apperance	10	4	0.40	2	0.20	4	0.40
Weighted Value Totals	100		3.90		4.35		3.60

Table 11, Rio de Flag Culvert Analysis Result

Rio de Flag CMP Culvert	
Velocity (ft/sec)	9.56
Headwater elevation (ft)	6793.94
Headwater Depth/Height	0.74
Control Type	Outlet control
Flow regime	Subcritical

- CulvertMaster used for analyses.
  - Determined velocity, headwater elevation, headwater depth/height ratio, control type.
- CMP Pipe scored high in cost, velocity, headwater elevation, and inlet/outlet protection.
- Headwater to match FEMA flood profile.

Post-Design Hydraulic Analysis - Rio de Flag Cont.

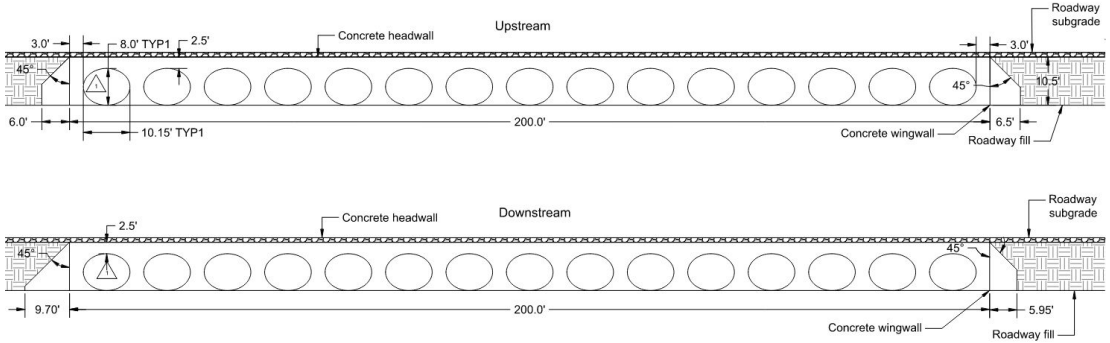


Figure 37, Rio de Flag Culvert Profile View

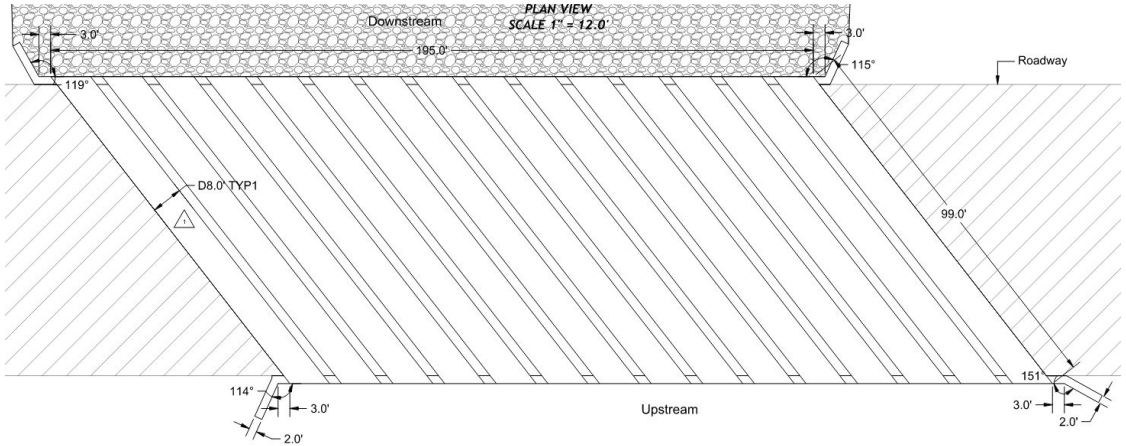


Figure 38, Rio de Flag Culvert Plan View

- 15, 8’ diameter CMP pipes
- Outlet protection required due to velocity
  - Dumped riprap
- Wingwalls on both upstream and downstream section
- Concrete headwalls

Post-Design Hydraulic Analysis - Pine Canyon Wash

Table 12, Pine Canyon Wash Crossing Decision Matrix

Pine Canyon - Water Crossing Type		Concrete Box Culvert		Corrugated Metal Pipe		Arch Culvert	
Criteria	% Weight	Value	Weighted Value	Value	Weighted Value	Value	Weighted Value
Cost	30	4	1.20	5	1.50	3	0.90
Velocity	25	2	0.50	4	1.00	2	0.50
Headwater Elevation	25	5	1.25	5	1.25	5	1.25
Required Outlet/Inlet Protection	10	3	0.30	4	0.40	3	0.30
Aesthetic Apperance	10	4	0.40	2	0.20	4	0.40
Weighted Value Totals	100		3.65		4.35		3.35

Table 13, Pine Canyon Culvert Analysis Result

Pine Canyon Wash CMP Culvert	
Velocity (ft/sec)	9.98
Headwater elevation (ft)	6809.91
Headwater Depth/Height	1.20
Control Type	Outlet control
Flow regime	Subcritical

- CMP again scores highly in cost and velocity, as well as outlet/inlet protection.
- Scored lower in headwater elevation.
  - Lower headwater was necessary, but not as pertinent as Rio de Flag crossing.

Post-Design Hydraulic Analysis - Pine Canyon Wash Cont.

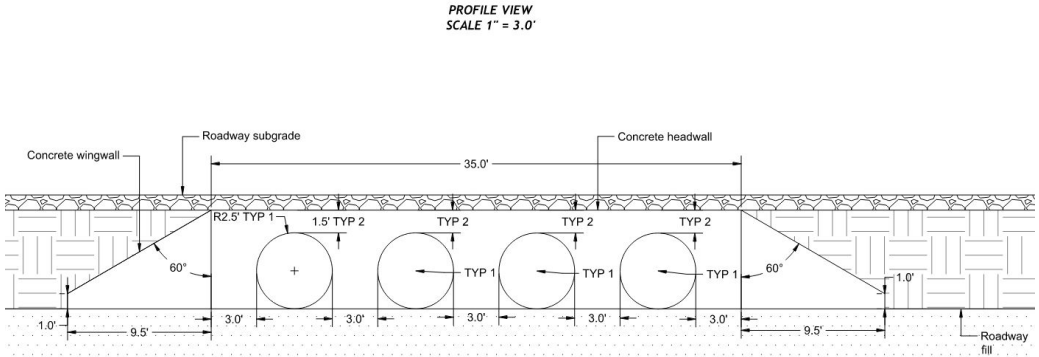


Figure 39, Pine Canyon Culvert Profile View

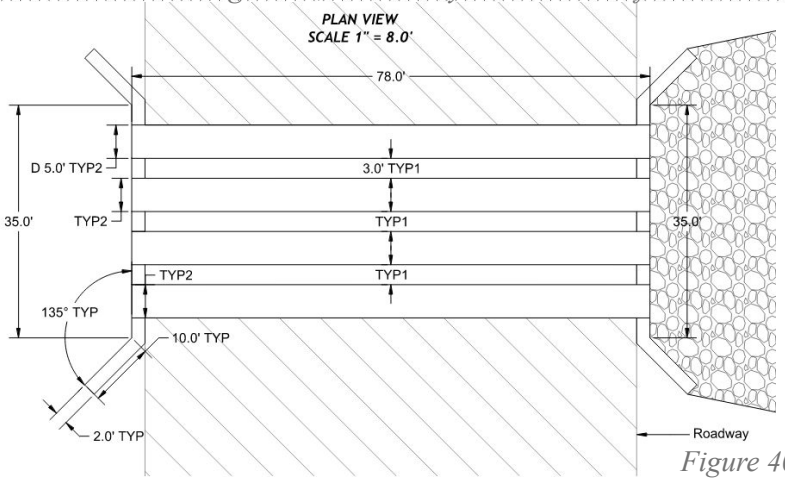


Figure 40, Pine Canyon Culvert Plan View

- 4 5’ diameter CMP pipes
- Outlet protection required due to velocity > 4 fps.
  - Dumped riprap
- Wingwalls on both upstream and downstream section
- Concrete headwalls

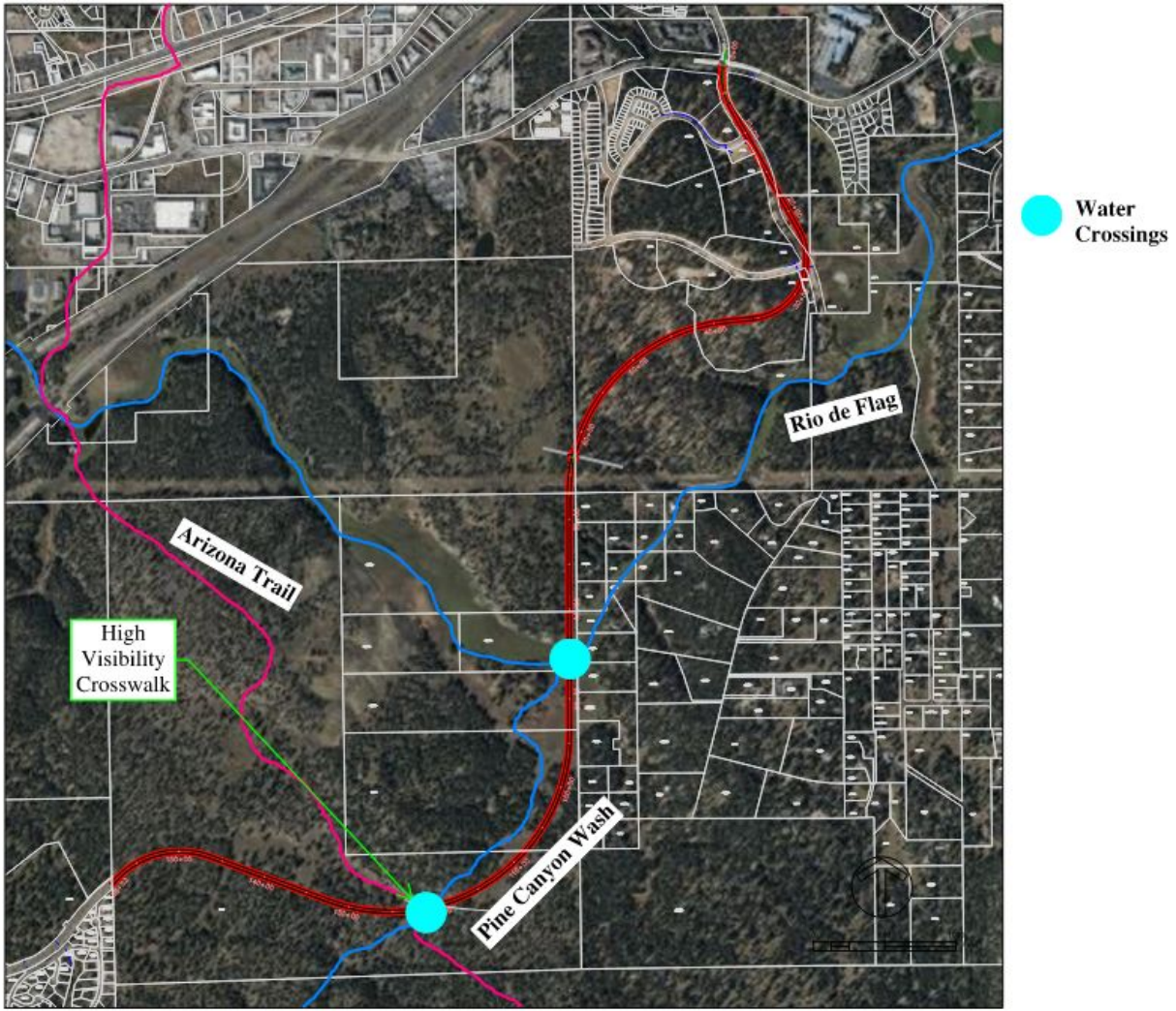


Figure 41, Major Crossings on JWP Alignment

Plan Set

Standard Detail Sheet

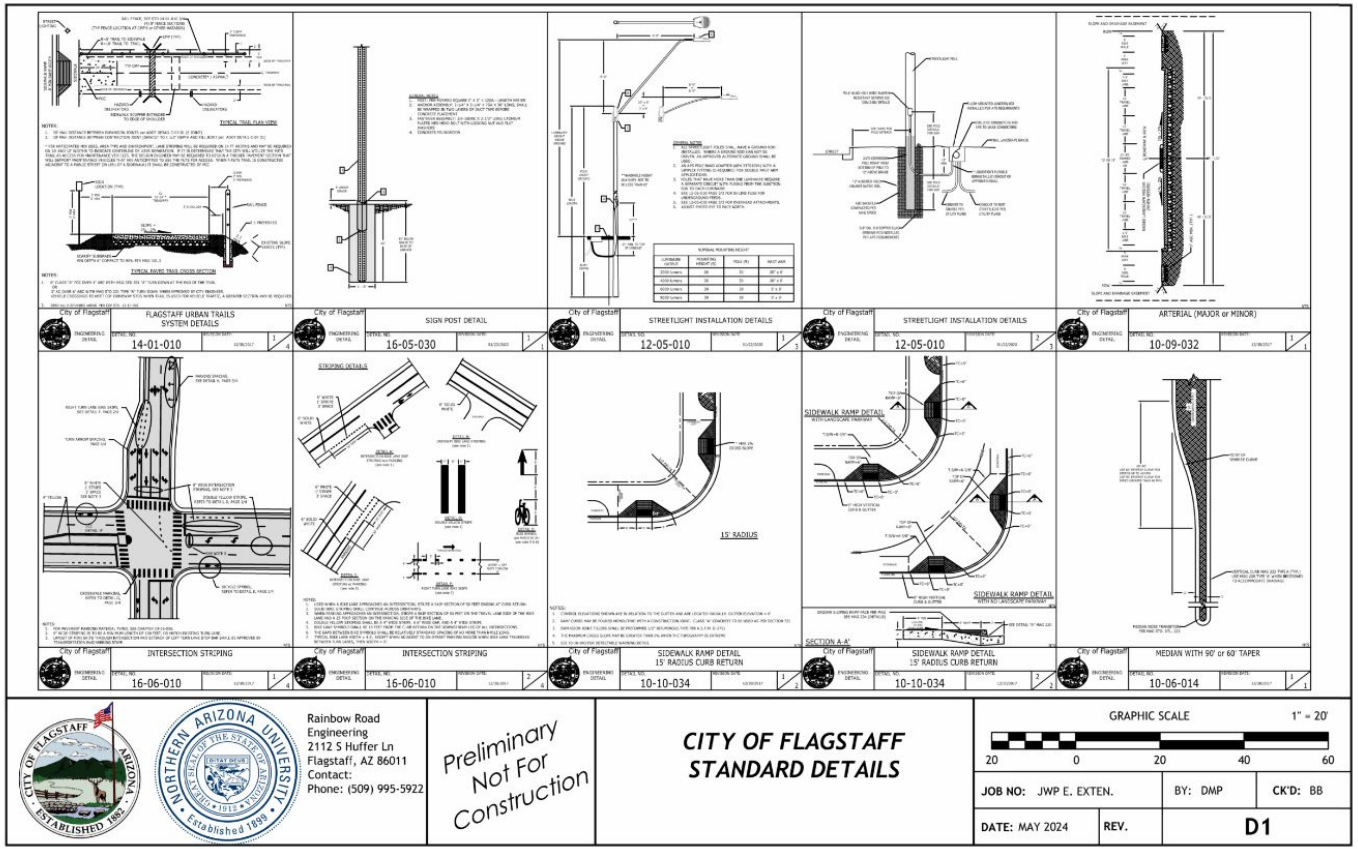


Figure 42, Plan and Profile Sheet

Plan and Profile Sheet

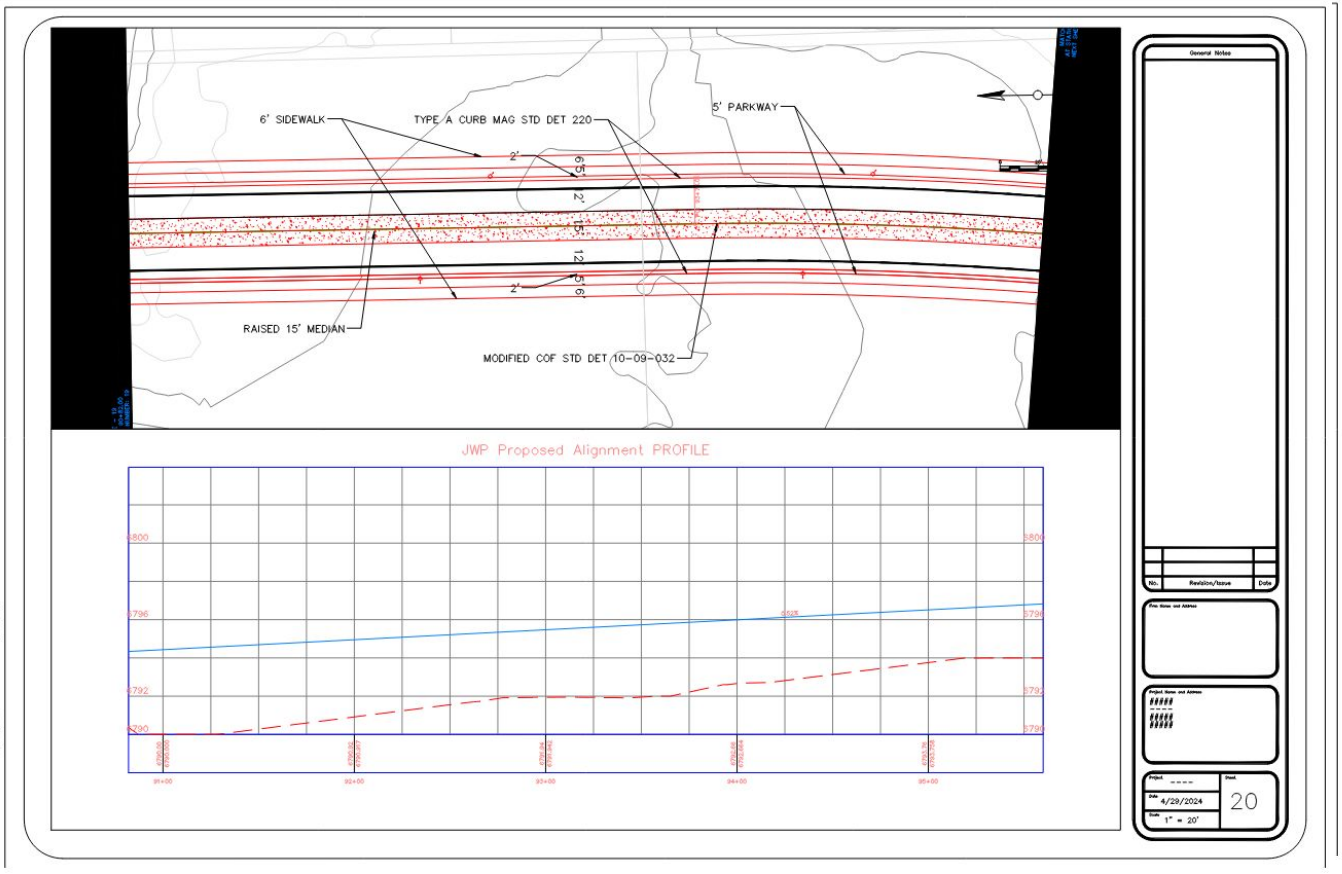


Figure 43, Example Plan Sheet

Construction Cost Estimate

Table 14, Construction Cost Estimate

	Item Description	Quantity	Unit	Unit Price		Total
DEMOLITION						
	Remove Trees	14080	EA	1000	$	14,080,000
				SUBTOTAL	**$**	**14,080,000**
EARTHWORK						
	General Excavation	417700	CY	30	$	12,531,000
	Borrow (In Place)	396200	CY	35	$	13,867,000
	Borrow (Off-Site)	21500	CY	250	$	5,375,000
				SUBTOTAL	**$**	**31,773,000**
ROADWAY						
	Asphalt Pavement	10000	TON	150	$	1,500,000
	Aggregate Base Course	24000	CY	85	$	2,040,000
	Concrete Sidewalk	95130	SF	18	$	1,712,340
	Curb Ramp	600	SF	20	$	12,000
	Curb and Gutter	15855	LF	45	$	713,475
				SUBTOTAL	**$**	**5,977,815**
SIGNING AND STRIPING						
	6" Solid White Line Stripe	31710	LF	1	$	31,710
	Speed Limit Sign	4	EA	80	$	320
	Bike Line Sign	4	EA	80	$	320
	Stop Sign	2	EA	80	$	160
	Nighttime Speed Limit Sign	2	EA	80	$	160
	Sign Post	30	LF	35	$	1,050
				SUBTOTAL	**$**	**33,720**
LANDSCAPING						
	Hydroseeding	5.5	AC	10000	$	55,000
				SUBTOTAL	**$**	**55,000**
DRAINAGE						
	8' CMP	1410	LF	500	$	705,000
	5' CMP	292	LF	400	$	116,800
				SUBTOTAL	**$**	**821,800**
				PROJECT TOTAL	**$**	**52,741,335**

- Major cost categories include:
  - Demolition
  - Earthwork
  - Roadway
  - Signing and Striping
  - Landscaping
  - Drainage
- Total project cost $52,741,335

Project Impacts

Economic

- Two urban centers
  - Restaurants
  - Shopping centers
  - Businesses
- Two large suburban areas
  - Additional housing
  - Increase real estate
- Large upfront cost
  - Large cut/fill
  - Funded by taxpayers

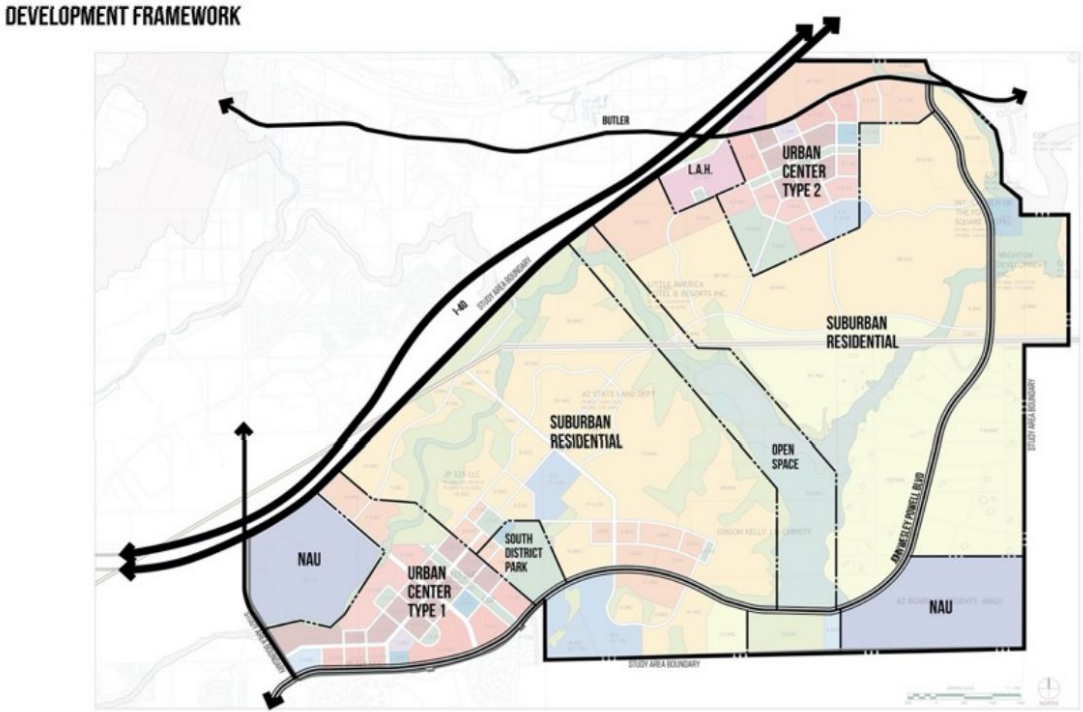


Figure 44, COF JWP Specific Plan [26]

Environmental

- Land alterations with urbanization
  - 14,080 trees removed
  - Loss of habitat
  - Disrupt existing wildlife
- Major wildlife crossing
  - Disrupt natural migration patterns
- Wildlife mitigation has been taken
  - Still fatalities from vehicle animal accidents
- Road alleviate traffic and pollution

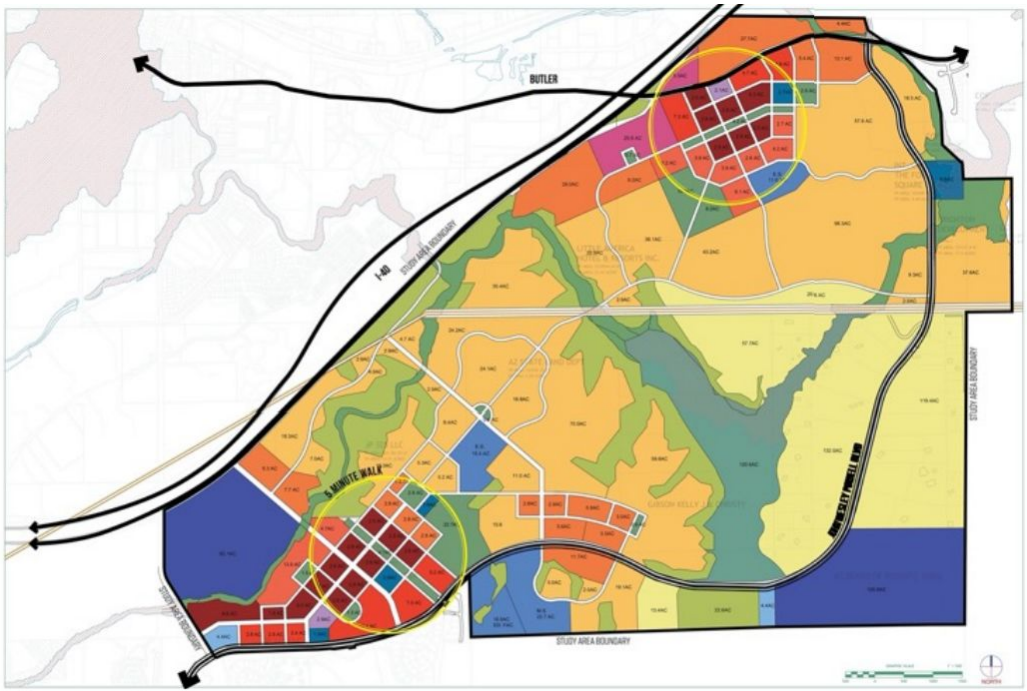


Figure 45, COF JWP Specific Plan Area Density[26]

Social

- Disruption to FUTS and AZ trail users
  - High visibility crosswalks
- Noise and dust with construction
- Lose of parcels to development
- More direct east-west bound travel path
- More urbanized areas
  - New parks

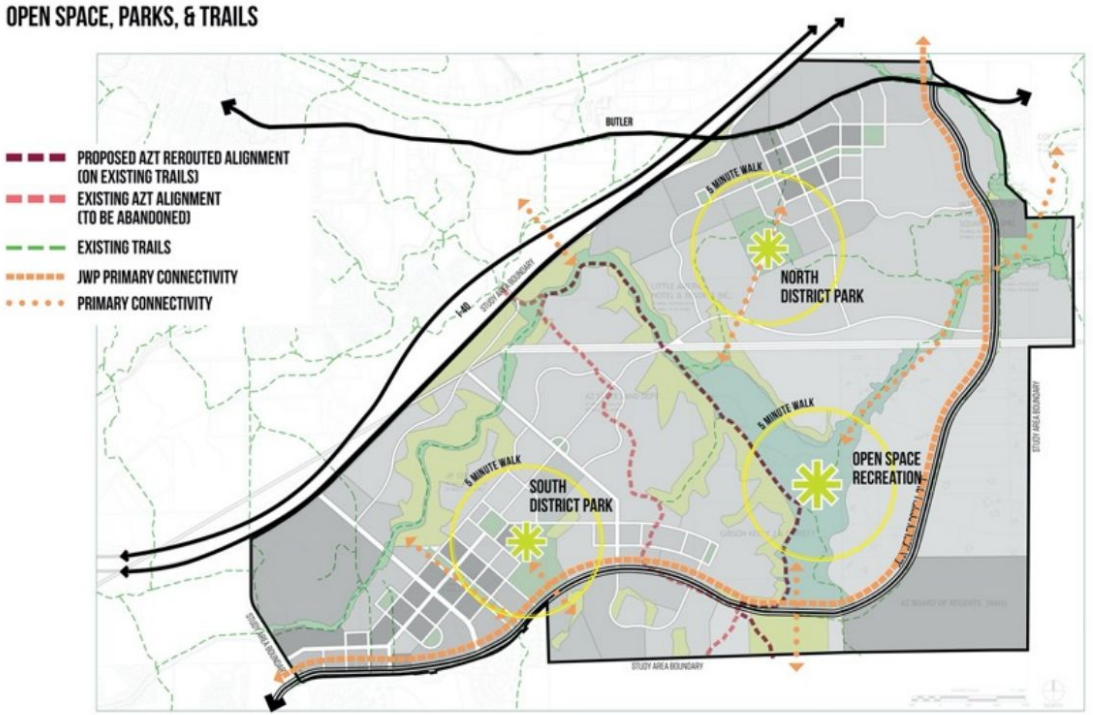


Figure 46, JWP Specific Parks and Open Space Map [26]

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Questions?