City of Avondale

Low Impact Development Street Tree Master Plan Supplement for Integrating Green Stormwater Infrastructure

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Green Stormwater Infrastructure Supplement Overview

The Green Stormwater Infrastructure Supplement to the Street Tree Master Plan provides guiding principles, standard street details, and performance metrics to ensure optimal design and performance of green stormwater infrastructure practices integrated into Avondale's roadways. Stormwater utilization to support street trees will help facilitate a sustainable, resilient City of Avondale with a unified and distinguished sense of place. Stormwater is a critical water resource that can be integrated and managed as part of a community's water portfolio safely and cost effectively through low impact development (LID) strategies. Green stormwater infrastructure (GSI) as a practice within LID serves to restore natural hydrological function while supporting associated landscapes and provides for a range of co-benefits including heat island mitigation, stormwater pollutant remediation, traffic calming, water conservation, etc.

The objectives of this Green Stormwater Infrastructure policy supplement are to:

- Facilitate integration of GSI into all roadway projects to support landscape and placemaking goals set by the Street Tree Master Plan
- Provide supportive understory planting plans to enhance Street Tree Master Plan aesthetic goals, while reducing maintenance concerns and maintaining roadway public safety
- Support achievement of Street Tree Master Plan shade canopy coverage goals
- Provide consumptive water use performance targets for street projects
- Establish performance goals and metrics to track progress made across the community.

Green Streets Performance Goals and Metrics

Representing over 25% of our public space, streets should be healthy, vibrant, and inviting "places to be." Integrating green stormwater infrastructure is critical to sustainably support shade trees and landscape amenities while helping to enhance all forms of community mobility, reduce stormwater pollutants, mitigate flooding, conserve water resources, improve air quality, reduce heat stress of vulnerable populations, and further Avondale's unique sense of place. The following performance goals are established to achieve optimal benefits from the integration of GSI. Associated performance metrics provide an assessment tool to measure progress towards achievement of stated goals.

To help ensure accountability for the performance goals and tracking of metrics it is suggested that City staff from the Development and Engineering Services Department and the Public Works Department work collaboratively to produce an annual report for submittal to the respective department directors for review.

Drainage Performance

Goals

1. Stormwater runoff from the roadway shall be directed through GSI basin features along roadways before entering storm drains or natural drainage ways.
2. Curbside landscape basin areas are designed to retain at least the following rainfall falling on the roadway:
    a. 80ft Collector Street = 1.00 inch rainfall
    b. 130ft Arterial Street = 1.00 inch rainfall

3. Median landscape areas on arterial streets are designed to retain at least a 2.00 inch rainfall event within the median.
4. GSI basins are designed to accept a maximum final pooling depth of 12 inches of stormwater.
5. All GSI basins must infiltrate retained stormwater within 24 hours following the end of the latest rain event.

Metrics

a) Retention volume of GSI features (cubic feet) within the public rights-of-way excluding the public utility easement (PUE)
b) Actual roadway rainfall event depth (inches) retained based on constructed GSI features
c) Percent of projects (i.e. capital improvement projects, retrofits, new development) integrating GSI features (%) in the public rights-of-way
d) Reduction in impervious area (square feet) for retrofit projects

Table 1. Representative drainage performance estimates for each street typology comparing total street runoff volumes to GSI basin volume. See appendix B for typology designs used to create these estimates

		(sf)	*(sf)*	*(cf)*	*(gal)*	*(cf)*	*(gal)*	*(cf)*	*(gal)*
Street Type	**Street Design Option**	**Street Catchment Area**	**Curbside Basin Area**	**0.50" Street Rainfall Runoff Volume**		**1.0" Street Rainfall Runoff Volume**		**Volume of Basins with 8" Ponding Depth**	
Arterial (160ft section)	12' lane width	6,840	900	257	1,900	513	3,850	540	4,050
	11' lane width	6,520	900	245	1,850	489	3,650	540	4,050
	11' lane with multi-path	5,880	820	221	1,650	441	3,300	547	4,100
Collector (120ft section)	12' lane width	3,000	680	225	1,700	450	3,400	480	3,600
	11' lane width	2,880	700	216	1,600	432	3,250	500	3,750
	11' lane with multi-path	2,400	680	180	1,350	360	2,700	480	3,600

Landscape Performance

Goals

1. Planting plan and associated plant water demand – once plants are established – is based on potential stormwater supply for average rainfall years (see tables 4 – 6).
2. Plant composition must include a minimum of 75% native, low water use plants (based on number of plants). All plants shall be in a low water use, drought tolerant category.
3. Canopy of shade trees, calculated at 100% of mature diameter based on species, covers at least the following public rights-of-way area (excluding the PUE) wherever possible given sight visibility constraints:
    a. 80ft Collector Street = 25%
    b. 130ft Arterial Street = 20%

4. Coverage of understory vegetation, based on 100% of mature diameter, covers at least the following curbside landscape areas to ensure GSI basin infiltration function:
    a. 80ft Collector Street = 25%
    b. 130ft Arterial Street = 25%
5. 100% of disturbed and or barren areas to be covered with native revegetation mix.

Metrics

a) Estimated annual water savings (acre-feet) due to reduction in irrigation by utilizing stormwater following plant establishment (3 years)
b) Number of shade trees (#) supported by GSI retention features
c) Change in shade tree canopy incorporated into retrofits of street projects (sq. feet or acres)
d) Percent composition of number of native plants to total number planted (%)
e) Percentage of disturbed areas and/or existing barren areas revegetated – including native revegetation seed mix (%)

Table 2. Representative landscape performance estimates for each street typology comparing rights-of-way (ROW) and landscape area to tree and understory plant canopy respectively. See appendix B for typology designs used to create these estimates

		(sf)	*(sf)*	*(sf)*	*(sf)*	*(%)*	*(%)*
Street Type	**Street Design Option**	**ROW Area**	**Tree Canopy**	**Landscape Area**	**Understory Canopy Area**	**ROW : Tree Canopy**	**Landscape : Understory**
Arterial (160ft section)	12' lane width	20,800	4,396	5,200	1,402	21%	27%
	11' lane width	20,800	4,396	5,840	1,452	21%	25%
	11’ lane with multi-path	20,800	4,396	5,680	1,402	21%	25%
Collector (120ft section)	12' lane width	9,600	2,512	2,160	660	26%	31%
	11' lane width	9,600	2,512	2,400	660	26%	28%
	11’ lane with multi-path	9,600	2,512	2,040	660	26%	32%

Community-scale Performance

Planning Process Metrics

- Updating documents (#) to integrate GSI/LID
- Engagement of public (# of events; type; methods) on GSI/LID related topics
- Training staff (#, hours of training, etc) on GSI/LID related topics
- Identification and inclusion of GSI/LID projects for funding (#)
- Number of inter-agency, cross organizational collaborations, new partnerships (# of partners) related to integrated GSI/LID roadway planning, design, construction, and/or maintenance
- Diversity (e.g. cross-departmental or topical expertise) of project team members and reviewers

Community Benefit Metrics

- Changes in walking/biking volumes and/or changes in transit ridership and/or average daily traffic (ADT) as appropriate (# per year)

- Quality of Life – Changes in the perceived quality of life of residents in neighborhoods adjacent to implemented projects (periodic survey incorporated into planning update process)
- Reduction in chronic flooding or flood risk (e.g. area, number of drainage complaints)
- Estimated return on investment received ($ received for each $1 spent)
- Economic Vitality measure (e.g. capital investment, percent employment, job creation, income distribution, etc.)

Green Stormwater Infrastructure Best Practices

Inlets, Flow Routing, and Grading

- Grading of the roadway surface will be planned and implemented to promote distribution of runoff into adjacent landscape areas. Grading within the landscape areas will ensure the ability to receive street runoff, distribute throughout planting area, and promote infiltration through the use of bio-retention basins, terraces, berms, and/or checkdams.
- Set the inlet to a GSI bio-retention basin at the upstream side of a basin and ensure each basin has an associated stormwater inlet to allow collection even with the smallest of rain events. This will ensure thorough soaking to support associated plants with each rainfall runoff event.
- GSI bio-retention basins should be designed with a single inlet/outlet to allow for use of organic mulch as a surface cover. The basins function as "backwater" basins which calm the flow and promote capture and remediation of stormwater pollutants as a "first flush" to the stormwater system.
- Provide for a minimum of 2" drop from curb inlet to top of rock or mulch in receiving basin.
- Ensure that if a sediment trap is incorporated then it is set at least 1-2" below the top of rock or mulch at the basin entry point for clear passage of stormwater into the basin.
- Basin slopes are ideally 4:1 but can be as steep as 3:1 if protected with riprap in order to increase storage capacity for enhanced infiltration and soil moisture storage.
- Basin slopes can be terraced to increase understory planting area and reduce appearance of deep drop between basin bottom and adjacent curb or sidewalk. Terrace elevation should be not higher than curb inlet elevation to retain basin volume and facilitate moisture access by plants.
- If flow is routed through a landscape section along a street then multiple inlets should be placed along the curb to ensure distribution of stormwater across the entire landscape area.

Surface Materials Selection and Placement

- Utilize organic mulch (preferably coarse chippings ~3-4" in length) as a surface cover applied 3-4" in depth. The use of organic mulch promotes healthy soils, the ability to process stormwater pollutants, cooler surface temperatures, enhanced soil moisture retention, and a reduction in germination of undesirable plants. The use of organic mulch also reduces maintenance and disposal costs since plant trimmings can be incorporated directly into surface mulch.
- Avoid use of rip-rap or cobbles at bottom of basins to ease maintenance tasks (e.g. trash removal) and reduce "staining" appearance from stormwater.
- Incorporate a sediment trap (bowl feature with rip rap lining and a downstream rocked lip) if routing concentrated flow into and through a landscape feature. Unless designing to meet a specific water quality goal GSI basins do not require a sediment trap as they function as the sediment trap for other downstream stormwater systems. Additionally, since maintenance does

not typically remove accumulated sediment in the GSI basin the sediment trap becomes an added cost for little to no value added.

- The use of decomposed granite, or “minus” material that includes fines and sediment, should never be used, since it can prevent infiltration within landscape and GSI basin areas.

Plant Selection and Placement

- Avoid use of “moderate” water use plants (e.g. pomegranates and elms) to allow for reliance on stormwater as primary irrigation resource.
- Develop “low-maintenance” preferred understory plant palette to accompany Street Tree Master Plan shade themes. Provide preference for low-profile, native, low-water use plants that provide an engineering and/or pollinator function. For example, small to mid-size native bunch grasses promote infiltration and uncompact soils without becoming overwhelming like the non-dwarf muhlenbergia species can become. Milkweed species provide critical habitat for Monarch butterflies. Utilize only accents and shrubs that are 3ft or under in mature height / width to reduce pruning of understory.
- Select and place trees appropriately to allow for minimal pruning during first 2 years of tree planting.
- Place trees on an elevated terrace equal or slightly above ponded surface elevation height adjacent to GSI basin.
- Plan for appropriate placement of understory species according to microclimate requirements with clump and gap arrangement to maximize biomass and habitat benefits.
- Develop an alternate plant list that can be readily used if specified plants are not available at time of project implementation. This will help to avoid the selection of an inappropriate plant is chosen for the project context and constraints.
- Avoid use of fast growing hybrids (e.g. Desert Museum Palo Verde tree or Chilean mesquite species) as they often result in being weakly rooted or limbed. Research shows native trees irrigated with stormwater associated with curb-side basins grow up to 30% faster and quickly reach full size.
- Select smaller stature trees if overhead utilities are present (e.g. acacia species).
- Specify larger planting sizes for trees which may impact sight visibility in the first few years of growth. This will allow selective pruning to maintain sight lines.
- Maintain an updated tree selection list that accounts for experience with tree response to local conditions and incorporates air quality considerations (e.g. avoid high VOC trees).
- Plan layout of understory vegetation based on 100% of mature diameter.
- Native bunch grasses should be part of the plant palette for bio-retention basin and drainage bottoms. The dense fibrous root systems promote water infiltration and stability along conveyance swales by reducing potential for erosional scour of the soil surface. Only utilize native grass species as non-native grasses spread easily and adversely impact urban and natural environments. To avoid grass becoming a fire hazard use in small groupings with gaps between groupings.

Irrigation Budgeting with Stormwater

The following information is specific to green stormwater infrastructure (GSI) features and meant to supplement landscape watering guidelines specified in the Street Tree Master Plan. However, variance from the Street Tree Master Plan guidelines should be noted due to the integration and utilization of stormwater as a resource.

The development of the GSI street typology designs incorporated water conservation goals to facilitate long-term water sustainability. Irrigation guidelines and water budgets were developed for each specific major street typology and correspond to the spacing and layout of the landscape features.

It is recommended that installed irrigation systems should be utilized for landscape establishment periods only (1 - 5 years) and irrigation frequency should be gradually reduced after the 2nd year. In seasons with rainfall well-below average (less than 75% of average) a plan should be in place for supplemental irrigation through either a) temporarily turning on the irrigation system, or b) utilizing a water truck. Typically, this is only needed ~1x per month during the dry, warm months. It may be preferable to use a bubbler irrigation system for directing supplemental irrigation into basin areas to facilitate simple, low cost, and easily maintained irrigation systems.

Once plants are established stormwater provides the irrigation benefits to the associated plants. Infrequent deep soaks are important for healthy root development. Conventional irrigation systems inhibit this healthy root development by overwatering and keeping soil moisture artificially high in the upper soil profile near to the plant. In addition, overwatering causes plants to have longer growth periods and put more energy into the above ground portion of the plant rather than investing in robust root development. This can exacerbate maintenance costs by increasing pruning frequency and making larger plants more susceptible to wind throw during storm events. Table 3 provides a suggested irrigation scheduled by month.

Table 3. Irrigation guide for green stormwater infrastructure features with low-water use, native plants.

	Months					
Year	Jan - Feb	March- April	May-June	July-Aug	Sept-Oct	Nov-Dec
1	Follow general establishment schedule based on soil type, season, and canopy size.					
2	1x/month	deep soak 2x/month	deep soak 2x/month	deep soak 2x/month	deep soak 2x/month	1x/month
3	None	deep soak 1x/month	deep soak 1x/month	deep soak 1x/month	deep soak 1x/month	None
4	None	deep soak 1x/month	deep soak 1x/month	deep soak 1x/month if no recent rain	deep soak 1x/month if no recent rain	None
5+	None	None	deep soak 1x/month may be desired for aesthetics	deep soak 1x/month if no recent rain	deep soak 1x/month if no recent rain	None

Note: If temperatures are above average and without meaningful rainfall (>0.1”) for a month or more than an irrigation cycle may be needed to maintain desired plant aesthetics.

Supply and Demand for Arterial Streets

Table 4. Estimated curb-side GSI landscape water budget per 160 feet section of an arterial street (see Appendix B). GSI landscape includes 6 native, low water use trees and 500 sq.ft. of associated low water use understory plants.

	Month (values reported in gallons)												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Storm water Supply	4670	3810	4380	980	370	80	4750	5160	3560	2990	2330	3190	36,280
Plant Water Demand	450	820	1490	2600	3320	3570	3030	2620	2200	1600	890	500	23,100
Supplemental Demand *	0	0	0	-1620	-2950	-3480	0	0	0	0	0	0	13,180 Surplus

Assumptions: Consumptive water use is based on average annual rainfall (8.86”); 20feet diameter tree.
*Months indicating a need for supplemental irrigation supply does not take into account either stored soil moisture from previous months or native plant drought dormancy adaptations.

Table 5. Estimated roadway center median water budget per 160 feet section of an arterial street (see Appendix B). GSI landscape includes 2 native, low water use trees and 450 sq.ft. of associated very low water use understory plants.

	Month (values reported in gallons)												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Storm water Supply	1070	870	1000	220	80	20	1080	1180	810	680	530	730	8,280
Plant Water Demand	200	360	650	1130	1450	1550	1320	1140	960	690	390	220	10,060
Supplemental Demand *	0	0	0	-910	-1360	-1540	-240	0	-140	-10	0	0	-1,780 Deficit

Supply and Demand for Collector Streets

Table 6. Estimated curb-side GSI landscape water budget per 120 feet section of a collector street (see Appendix B). GSI landscape includes 8 native, low water use trees and 660 sq.ft. of associated low water use understory plants

	Month (values reported in gallons)												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall Supply	4690	3830	4400	990	370	80	4770	5180	3580	3000	2340	3210	36,450
Plant Water Demand	680	1230	2250	3920	5000	5370	4560	3950	3310	2400	1340	750	34,770
Supplemental Demand*	0	0	0	-2930	-4630	-5290	0	0	0	0	0	0	1,680 Surplus

Nurturing Maintenance Practices

The following information is specific to green stormwater infrastructure (GSI) features and meant to supplement maintenance guidelines specified in the Street Tree Master Plan. Green stormwater infrastructure systems utilize natural processes in a constructed environment to provide community services including stormwater pollutant filtration, infiltration, and bioremediation and support of shade trees. As a functional, engineered landscape appropriate maintenance is critical to improve system performance. By designing for maintenance and providing appropriate maintenance practices a GSI system's performance should improve as the landscape matures. Appropriate maintenance should not be seen as "cleaning" the landscape rather it should be seen as "nurturing" the landscape.

GSI requires a shift toward support of naturalized systems. As naturalized systems, irrigation and maintenance are focused on ensuring health during the critical establishment period in order to maintain ecological function and associated benefits in the long-term. These practices reinforce the potential benefits of green stormwater infrastructure features through conservation of water resources by reducing supplemental irrigation demands (see tables 4 - 6). Far too often maintenance degrades the performance of GSI systems and provides little to no irrigation savings benefit. This section will focus on maintenance best practices for GSI systems as it applies to the street typologies presented.

The health and performance of GSI is based on the health of the underlying soil. A Tucson, AZ based study of GSI showed that within a few short years the native soil ecosystem attained the diversity of a mature forest soil if certain conditions were maintained[1]. These GSI systems all utilized native soil without soil conditioning amendments and included native plant understory and trees, organic surface mulch (tree trimmings), and received street stormwater were much more diverse than surrounding soils that did not receive stormwater inputs or GSI systems that utilized rock mulch instead of organic mulch.

Soil health also relates to the ability to infiltrate, percolate, and store plant bio-available moisture. Organic content in a soil is critical to all of these processes. Urban soils typically are lifeless, dry, and compacted. Plants and their associated roots and leaf litter add organic content and help to uncompact soil providing the support to re-establish a healthy soil ecosystem that can process stormwater pollutants and convert many of those pollutants to nutrients to support plant growth.

The establishment maintenance period of a GSI system should focus on being a catalyst to develop soil health. This includes minimizing soil surface disturbances to promote fungal (e.g. mycorrhizal) colonization and development and minimize weedy (early colonizer) species ability to propagate. This includes applying woody mulch, not raking the soil surface, and addressing weedy species early in the growth season with appropriate maintenance techniques.

Weed management during the growth seasons should be built into the more frequent general cleaning and trash removal. GSI as a stormwater collector functions as a great trash collector. This should be viewed as a positive as it is better to collect along streets versus in downstream water bodies and natural areas. Additionally, it can be informative of where/who are the major sources of trash and develop programs/messaging to reduce trash production. Table 7 provides a suggested maintenance schedule for GSI features.

Education and training should be provided on weed identification and appropriate integrated pest management (IPM) options. Many weeds are actually beneficial annuals or perennials that can help

[1] Pavao-Zuckerman, M.A., and Sookhdeo, C. 2017. Nematode community response to green infrastructure design in a semi-arid city. Journal of Environmental Quality 46, 687-694.

naturalize a desert landscape, stabilize the soil surface, be a pollinator, and add organic content. Raking or scraping the soil surface to remove many of these annuals perpetuates a weed maintenance problem beyond the establishment phase and may provide seeding ground to more aggressive invasive species.

Lastly, as GSI features utilize natural systems and thus should improve in performance as they mature it is critical that the landscape is nurtured to be productive. The health of the plants is far too often reduced within the first couple of years due to poor pruning practices. Ensure pruning of plants maintains natural form of plant or tree through selective pruning (no hedging, liontailing, topping, etc). This will reduce the mortality rate of plants, ensure infiltration and soil remediation performance of the GSI feature, and maximize the return on investment.

Table 7. Current and recommended maintenance items for green stormwater infrastructure features.

Maintenance Item	**Current Frequency**	**Recommendation**
Cleaning/Weed Control	Bi-weekly to Monthly	Focus on trash removal and manual removal of problematic weeds (no spray or raking options). Frequency should be greater during wetter months.
Mulch replenishment	Every 2-5 years	Inspect for need to replenish organic mulch if not sufficiently replenished during plant pruning and chipping process. Typically, plant leaf litter and pruning chippings are sufficient to maintain organic mulch cover.
Pre-Emergence	Semi-annual	Shift to an Integrative Pest Management system to eliminate/minimize need for herbicide applications.
Post-Emergent	Semi-annual	Shift to an Integrative Pest Management system to eliminate/minimize need for herbicide applications.
Shrub/Groundcover Maintenance	Quarterly	No topiary pruning or hedging; replace groundcover as needed to maintain minimum 25% coverage.
Tree Maintenance	Annually	Years 1-3: Conducted semi-annually before and after growing season, light pruning to maintain site visibility and clearance, overseen by certified arborist Years 4+: Annual pruning, overseen by certified arborist; avoid summer pruning
Irrigation Inspection & Maintenance	Monthly	Years 1-2: Regular irrigation schedule Years 3-5: Reduce/eliminate irrigation during winter months (Nov – Feb) Years 5+: Reduce/eliminate irrigation for most of year unless abnormally dry & hot or to maintain aesthetics May – June. Supplemental watering 1/month during warm, dry season may be desired to maintain plant aesthetics
GSI Performance Inspection & Maintenance	Semi-annual / Periodic	Sediment: accumulation of sediment in the sediment trap or basin bottom should be removed only if it reduces the ability to meet performance objectives of the GSI feature from either a water quality or retention volume perspective. Often sediment acts as a mulch as long as vegetative cover is present to reduce evaporative water loss and infiltration rates are not impacted. Ponding: check for ponded water 2-3 days following rain events. If ponding persists then take appropriate action to A) decompact underlying soil, B) integrate organic mulch or compost, and C) re-establish native plants (i.e. native grasses) to facilitate infiltration

Appendix A

Estimated Value of Benefits Received from Green Stormwater Infrastructure Features

A detailed summary of economic values calculated for a typical arterial street typology with integrated green stormwater infrastructure can be found in Table 8. A summary analysis is provided for an arterial street (see Appendix B) as part of new or redevelopment of the street as well as for retrofitting a street.

For additional details on the research that supports these costs see the footnotes, i-Tree references, Autocase For Sites, and the Business Case Evaluator (BCE) report 'Evaluation of GI/LID Benefits in the Pima County Environment'. Regression analyses, cost data based on Watershed Management Group's experience and outputs from these tools were summarized in a Microsoft Excel spreadsheet tool.

Direct Benefits

Water Conservation – Water demand during establishment for rain gardens was based on low water use plants for two native trees, 4 grasses, and 2 groundcover plants for every 140 square feet of landscape area that has a stormwater basin associated. It is assumed that GSI has similar irrigation efficiencies as flood irrigation. Flood irrigation efficiencies range from 40-85%. A conservative value of 50% is used here. It is assumed that irrigation to GSI associated plants is discontinued after the first 3 years of plant establishment. Financial savings due to reduced water demand from the utility are based on an average of the three tiers for a 1" meter associated with City of Avondale's non-residential rates established in February 2018.

Air Quality Improvement – The BCE tool was used to define a relationship between number of trees planted and benefit value. Air quality benefits are calculated in the BCE as the sum of reduced emissions of air pollutants from power-generating plants, and the value of pollutant uptake from trees.

Reduced Street Maintenance – Shade created by trees installed with LID extends the life of asphalt pavement, reducing the maintenance required. As shown by McPherson & Muchnick[2], significant financial savings can occur from pavement shading. This benefit may not fully apply to a four season environment with snow and ice conditions.

Avoided Grey Infrastructure – Potential savings of large scale flood mitigation infrastructure if LID retention is taken into account in sizing detention basins, storm drains or culverts. Values used in the cost-benefit analysis (CBA) are based on the cost estimates of proposed grey alternatives to alleviate flooding in an urban subwatershed located in the City of Tucson and part of the Airport Wash study area using conservative estimates of savings. Additionally included in this benefit is the amount of water intercepted by trees planted, estimated using the i-Tree Streets tool. McPherson et al.[3] used Glendale, Arizona's cost for retention/detention basins to determine the value of water collected and stored by trees.

Indirect Benefits

Social Value of Water Conservation - The indirect cost of water is determined by the cost of water augmentation from alternative water sources. The cost of water from alternative sources is based on a 2010 report which highlighted cost per gallon over a 10-year period for three new sources. The CBA

[2] McPherson, E.G., J. Muchnick. 2005. Effects of street tree shade on asphalt concrete pavement performance. Journal of Arboriculture 31(6): 303-310.

[3] McPherson, E.G., J.R. Simpson, P.J. Peper, S.E. Maco & Q. Xiao. 2005. City of Glendale, Arizona Municipal Forest Resource Analysis. USDA Forest Service, Pacific Southwest Research, Center for Urban Forest Research.

analysis assumed the cheapest alternative is implemented and expanded to a 100-year period for assessing cost per gallon.

Table 8. Benefit cost analysis comparison for an arterial 160ft section with integrated green stormwater infrastructure features based on an arterial green street typology (See Arterial Street detail – separate document).

Inputs	New or Re-Construction	Retrofit
Trees #	14	12
Basin Area (SF)	3720	3080
Basin Depth (Ft)	0.667	0.5
# Traffic Calming Elements[4]	.5	.5
Direct Annual Benefit Estimates		
Water Conservation	$691	$572
Air Quality Improvement	$111	$95
Energy Savings	$83	$71
Street Maintenance	$91	$78
Grey Infrastructure Avoided	$184	$121
Property Value	$12	$10
Indirect Annual Benefit Estimates		
Social Value of Water Conservation	$960	$795
Greenhouse gas emissions reductions	$94	$80
Flood Risk Reduction	$29	$18
Energy Cost of Water	$127	$105
Stormwater Pollution Reduction –data not available	$0	$0
Traffic Calming	$924	$924
Urban Heat Island	$14	$11
Total Annual Benefits	**$3,317**	**$2,880**
Cost Estimates	**New or Re-Construction**	**Retrofit**
Total Capital costs	$14,349	$20,405
Total Annual Maintenance	$831	$688
Benefit Cost Estimates		
Net Present Value (NPV) Benefits/SF	$39	$43
NPV Costs/SF	-$6	-$9
NPV CBA/SF	$33	$34
$ Capital expense per gallon of basin volume	$0.52	$0.89
No. of Years for Return on Investment (7% discount rate)	4 years	6 years
Direct Benefit : Cost	$2.87	$1.98
Total Benefit : Cost	$6.42	$4.94

[4] The number of traffic calming elements is a conservative estimate with not more than one element per block based on the assumption that street basins immediately next to each other are not likely to provide independent traffic calming benefits. The typical city block length is 16 or 17 per mile (~310 feet).

Greenhouse Gas Emissions Reduction – The carbon reduction value from the BCE was calculated by subtracting the carbon emissions emitted during construction from the total benefits of decreased energy use in lifetime maintenance for the project and the carbon sequestration as a result of tree plantings. The average value for carbon emissions utilized based on BCE research is $50/metric ton.

Flood Risk Reduction – The flood risk reduction value is based on water that is retained by water harvesting basins. The BCE models are based on rainfall in Tucson over the next 100 years to determine a rainfall model that is used to determine flood damages that are mitigated by the reduced runoff volume associated with active and passive rainwater harvesting.

Stormwater Pollution Reduction – Water harvesting basins and tree plantings provide the service of removing pollutants and heavy metals from runoff and treating them through natural filtration. There are regions in the southwest that have a stormwater utility fee that provides incentives for LID implementation to meet stormwater management needs. Property owners who implement LID have reduced utility fees as a means to incentivize LID. The City of Avondale has a stormwater utility fee that is $1.00 per month for each water account but does not have specific information in their stormwater management plan addressing water quality costs.

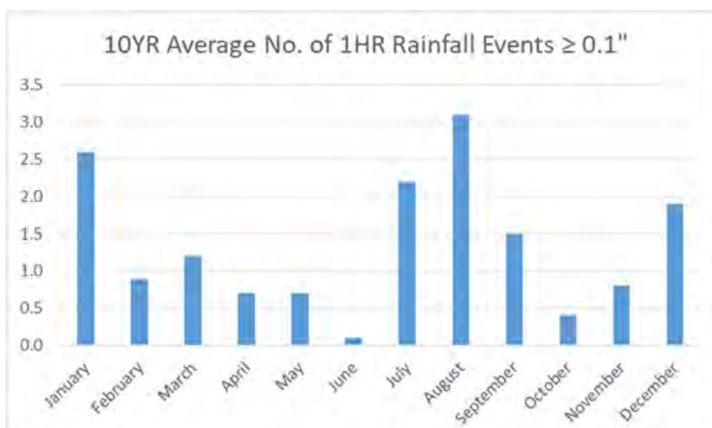
Traffic Calming – Traffic calming techniques such as roundabouts, curb extensions and changes to road environment (such as trees and shrubs) have been shown to reduce the frequency and severity of accidents. Following the procedure used by the Autocase tool, published Arizona crash rates and associated costs were combined with annual average daily traffic values for Avondale's Central Ave to estimate the potential benefit.

Rainfall Analysis

A rainfall event analysis was completed for the recent 10 year period of record to assess the average number of events per month that were greater than or equal to 0.1" of rainfall depth. The Luke Air Force Base (KLUF) weather station had the nearest dataset available which was accessed through MesoWest on October 30, 2018. The station is located at 33.53333, -112.38333.

Table 9. Average number of 1hour rainfall events ≥ 0.1" from 2008 to 2017. These events produce significant rainfall runoff to support plants associated with green stormwater infrastructure.

Month	Average # Events
January	2.6
February	0.9
March	1.2
April	0.7
May	0.7
June	0.1
July	2.2
August	3.1
September	1.5
October	0.4
November	0.8
December	1.9
Annual Avg	16.1
Median	*14.5*



Annual Min # Events	*5*
Annual Max # Events	*38*

References

Low Impact Development (LID) Details for Alternative Stormwater Management. 2019. ASU Sustainable Cities Network. https://sustainability.asu.edu/sustainable-cities/resources/lid-handbook/

Green Infrastructure Manual for Desert Communities. 2018. Watershed Management Group. 2017. https://watershedmg.org/document/green-infrastructure-manual-for-desert-communities

Appendix B

Standard Street Typologies and Planting Palettes

See following pages.

City of Avondale
Street Tree Master Plan

Green Stormwater Infrastructure Supplement

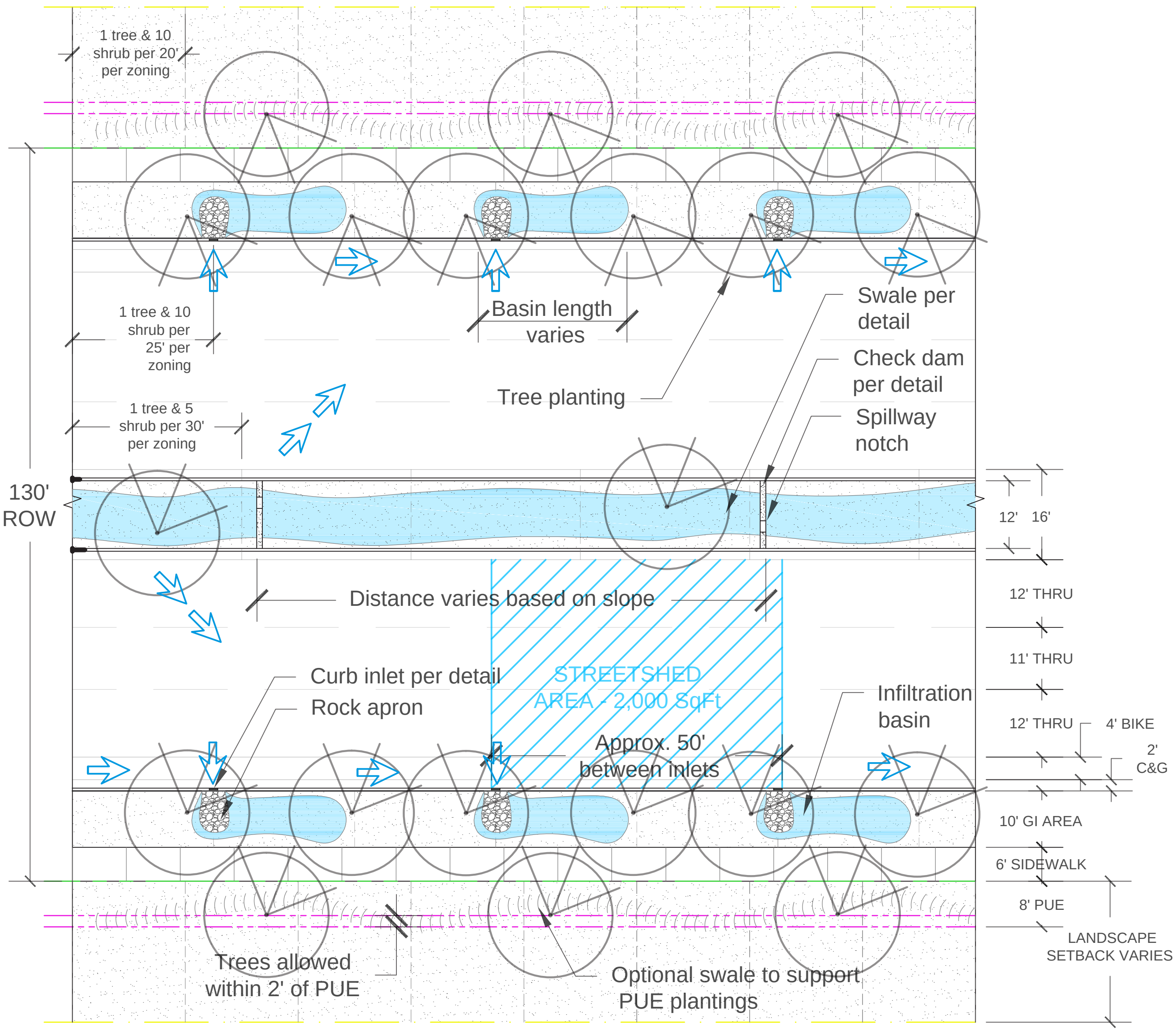
Standard
Street Typologies

Appendix B

Avondale
Aspiring. Achieving. Accelerating.

Watershed Management Group

WIFA



GREEN INFRASTRUCTURE NOTES

- Design for "eddy" (single inlet/outlet) basins which are preferable to allow use of organic mulch. Curb cut for all eddy basins shall be located on the upstream end of the basin to maximize basin capacity
- Basin length varies based on slope but not to exceed 40'. Reduce basin length along steeper slopes to avoid unplanned overflows
- Basins shall be designed for a ponding depth no greater than 12"
- Basins shall be designed with effective capacity to support plantings based on COA's average of 14 precip events per year
- Plantings in ROW and adjacent setback areas to be coordinated with the City for consistency where possible
- Trees to be planted adjacent to basin or if planting in basin, a planting shelf shall be provided
- See accompanying recommended plant list and notes on species selection herein
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REGULATORY NOTES

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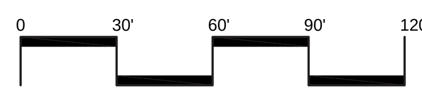
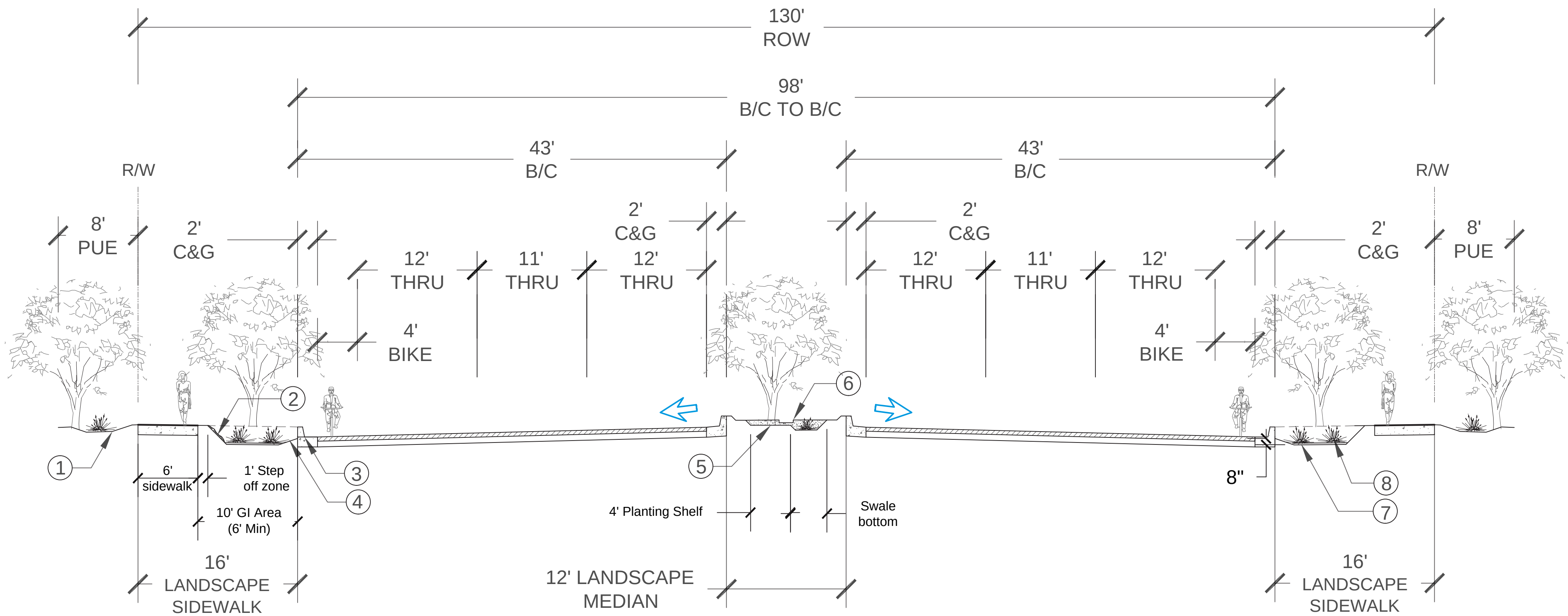
- All plantings within PUE shall be of shallow, non-intrusive root variety

130' ROW GSI INTEGRATION - TYPICAL STREET DESIGN

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT



SCALE 1" = 30'



KEY NOTES:

1. VEGETATED SWALE - See WMG Swale Detail and/or Phoenix Detail LID-06
2. BASIN - All slopes greater than 3:1 shall be reinforced with riprap. See WMG Basin detail and/or Phoenix Detail LID-05
3. CURB INLET - See WMG Curb Inlet Detail and/or Phoenix Detail LID-03
4. ROCK APRON - See WMG Rock Apron Detail and/or Phoenix Detail LID-03
5. PLANTING SHELF - See WMG Basin Detail
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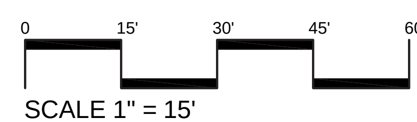
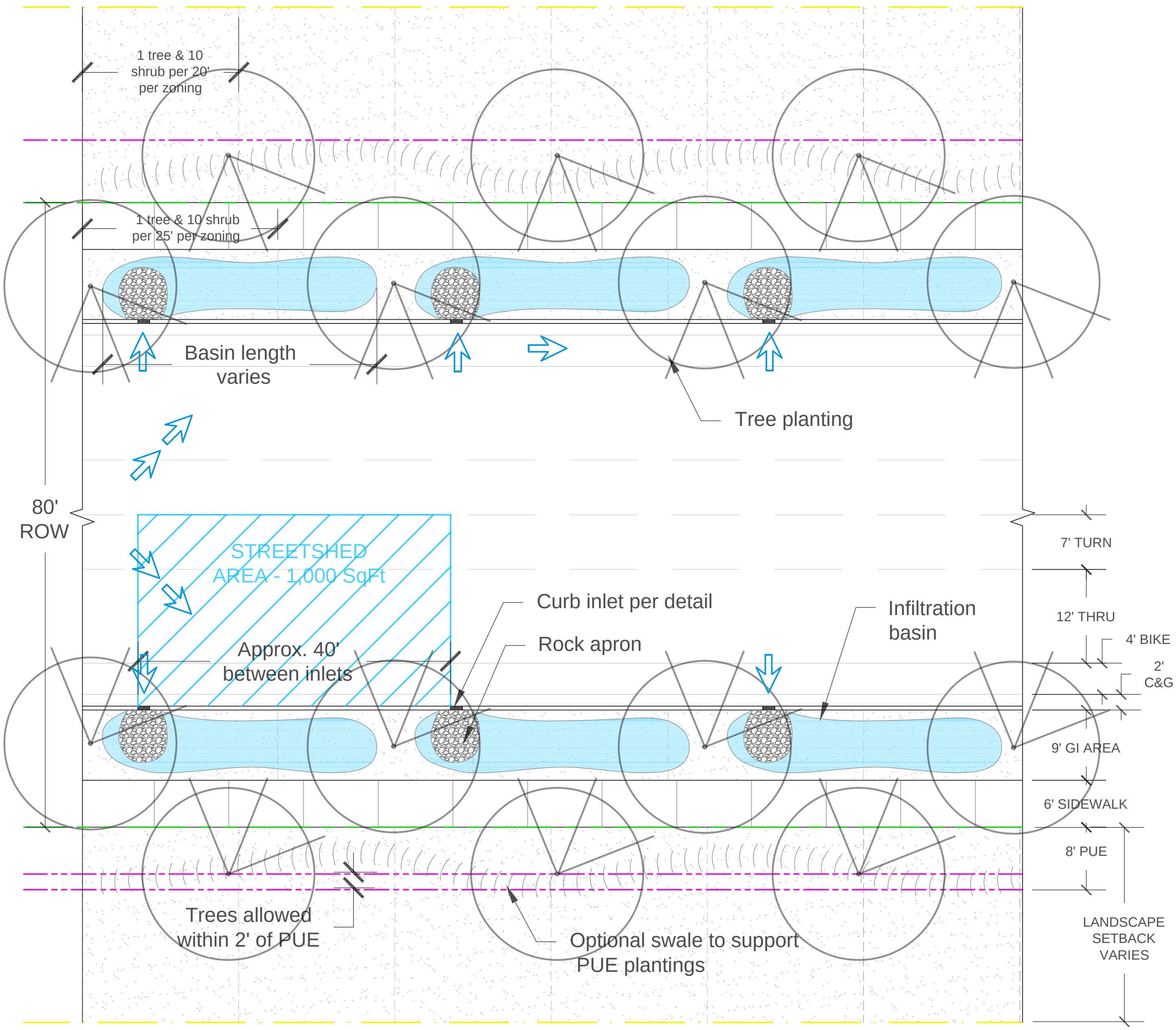
130' ROW GSI INTEGRATION - TYPICAL STREET DESIGN

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT





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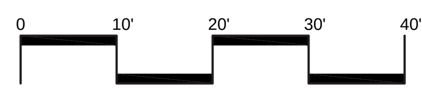

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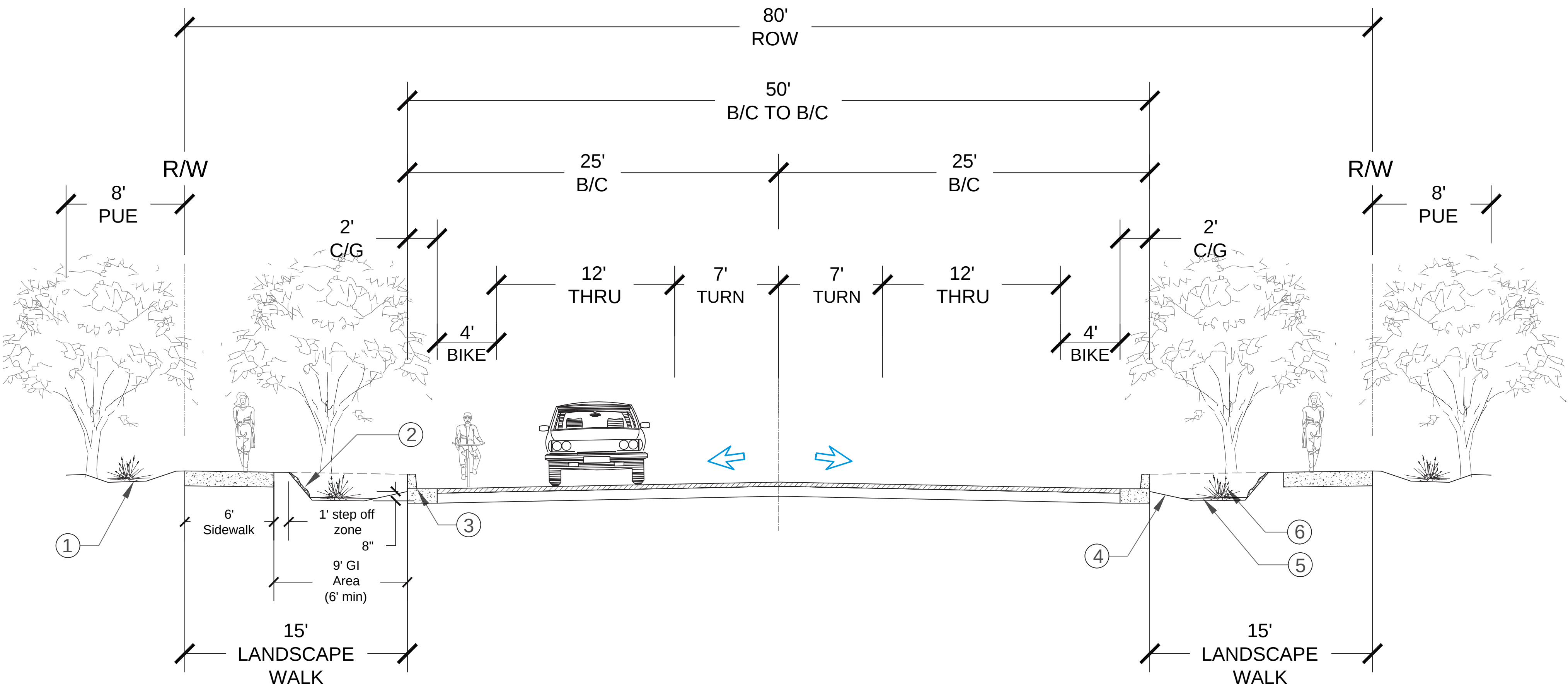
80' ROW GSI INTEGRATION - TYPICAL STREET DESIGN

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT



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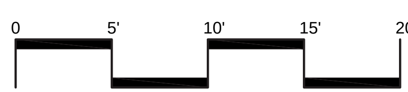
6. UNDERSTORY PLANTINGS - See accompanying recommended planting guide for appropriate species selections and groupings. See also the Phoenix Green Infrastructure & LID Handbook Landscaping Details and Specifications

80' ROW GSI INTEGRATION - TYPICAL STREET DESIGN

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT



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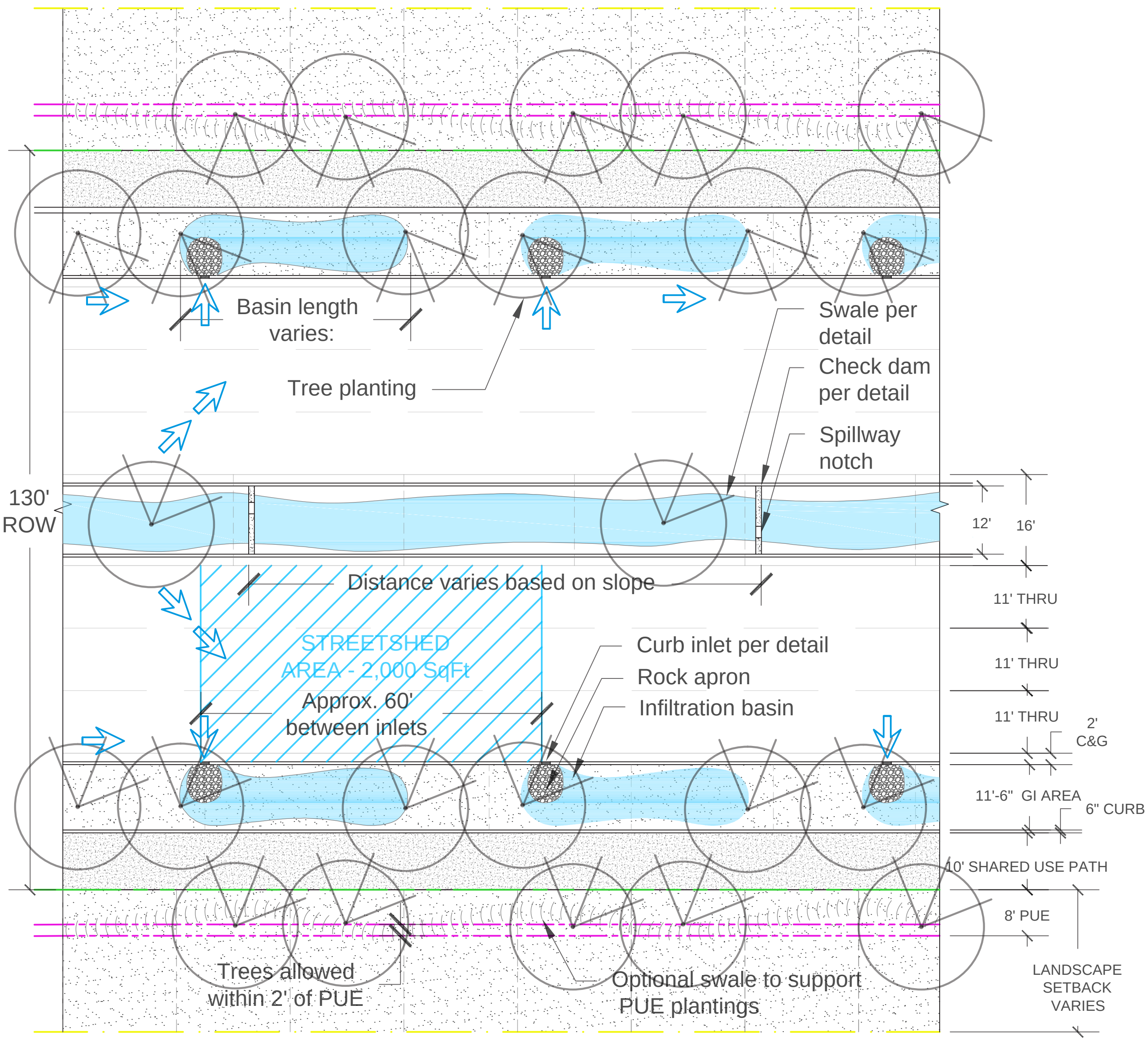

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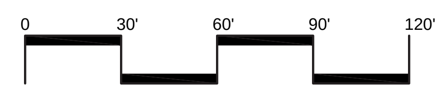
130' ROW GSI INTEGRATION - TYPICAL STREET DESIGN WITH SHARED USE PATH

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT



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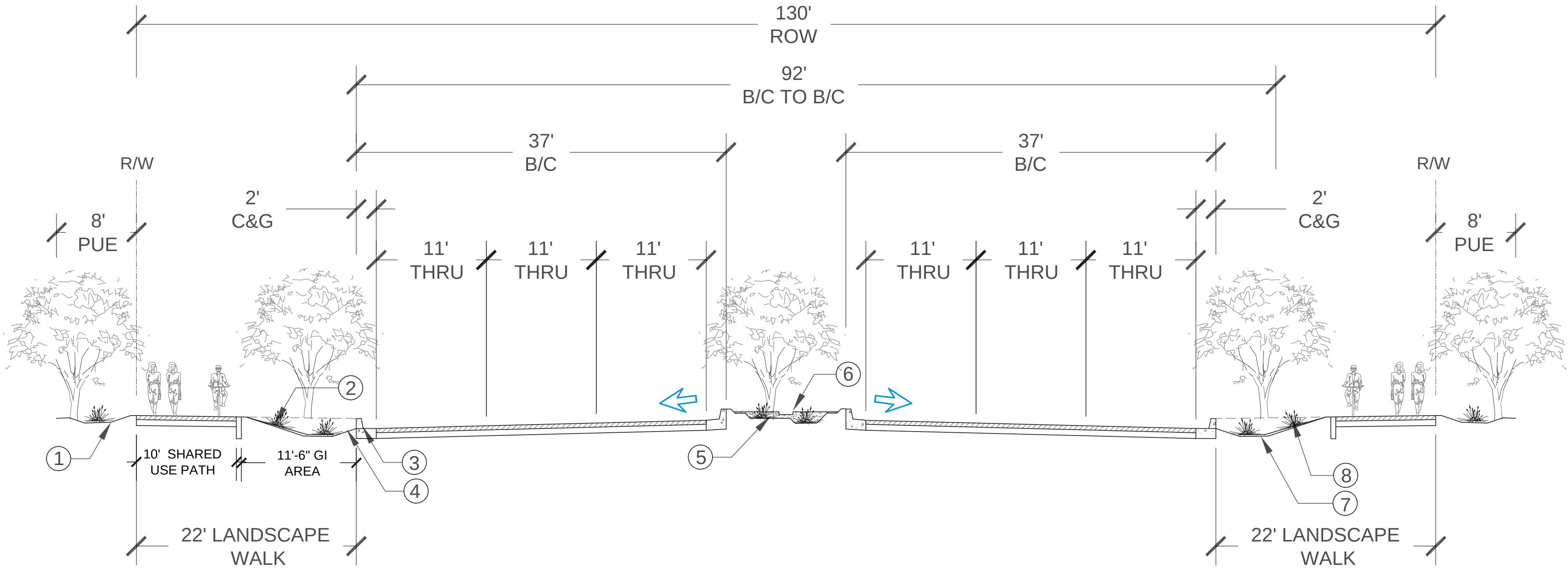

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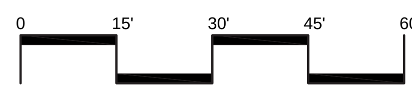

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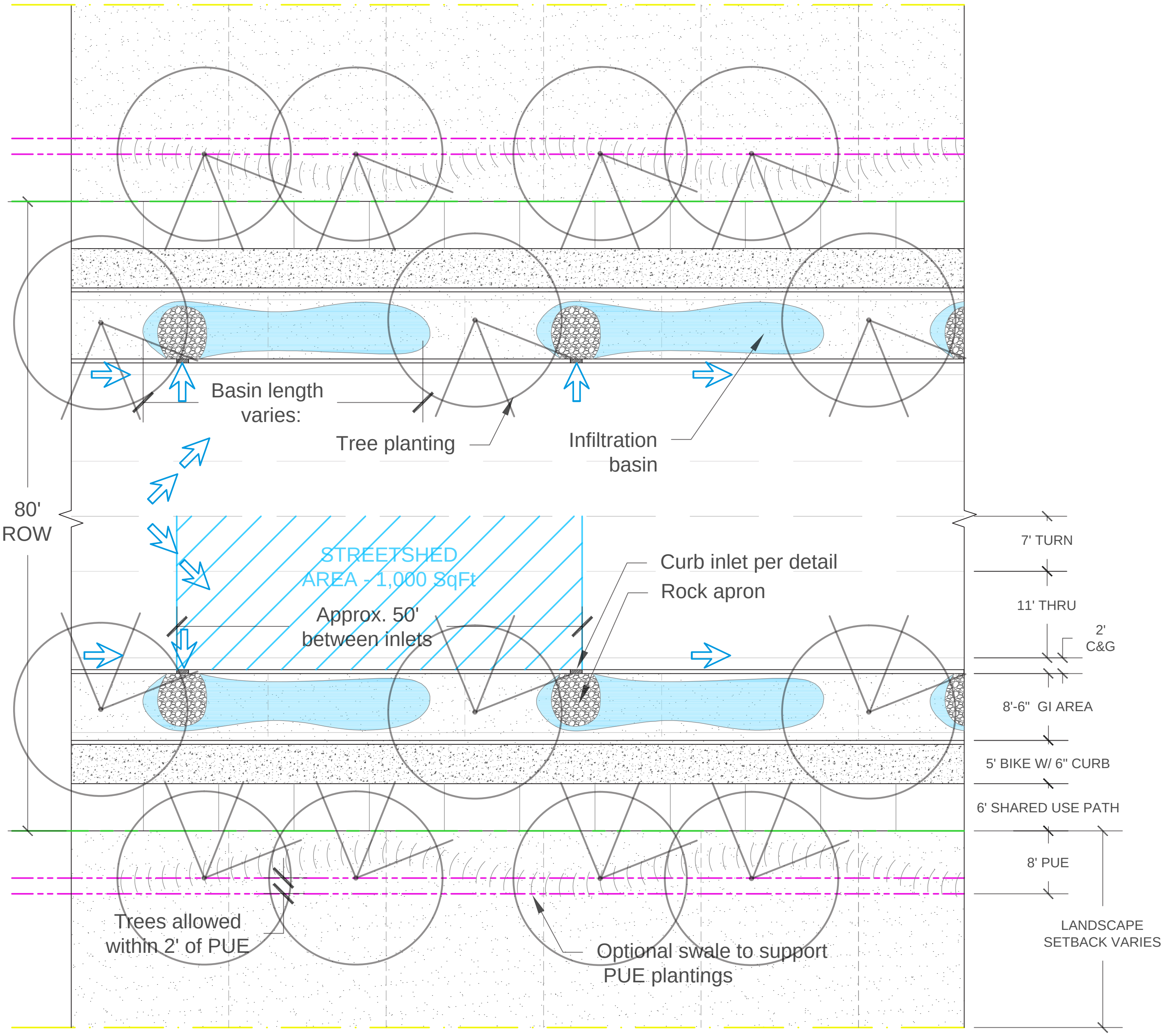

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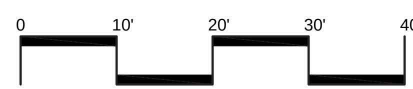

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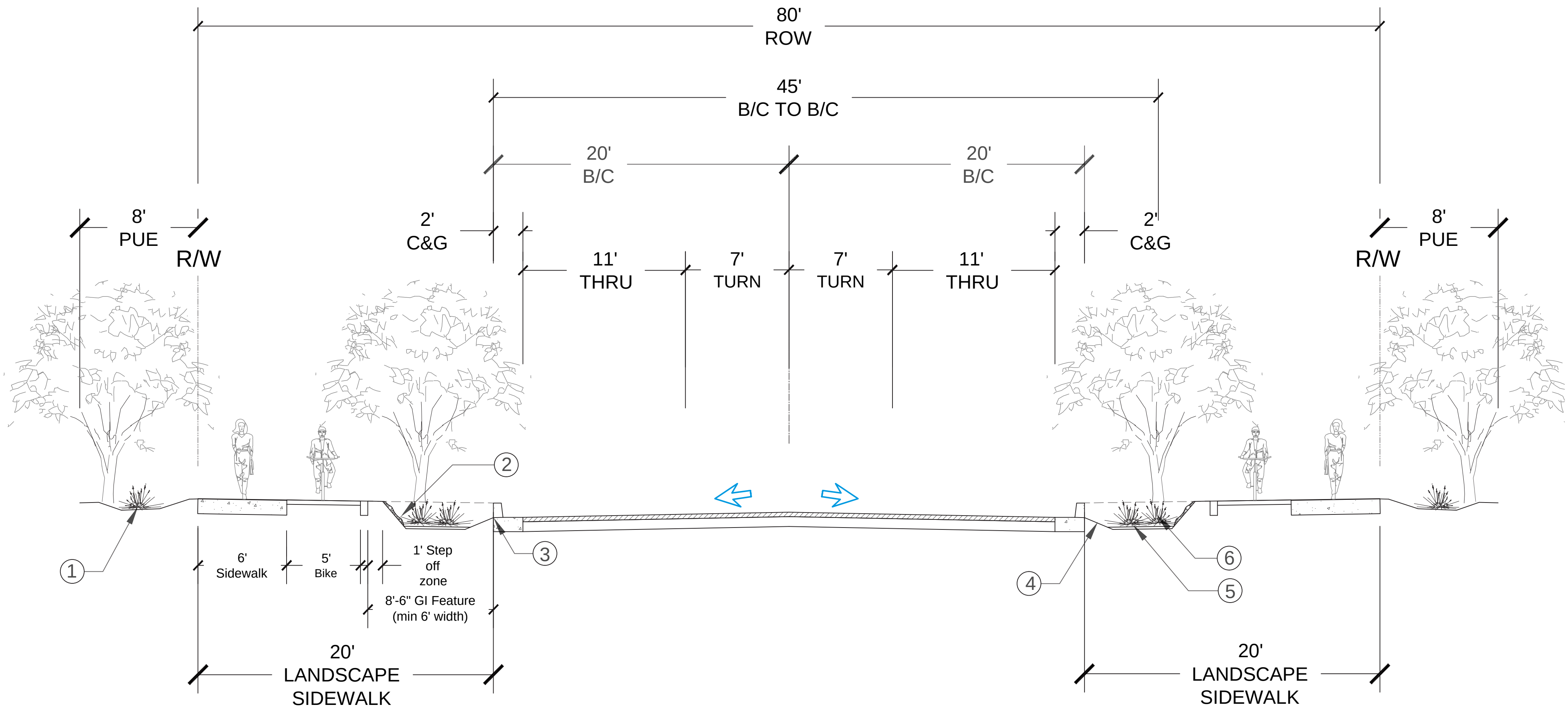

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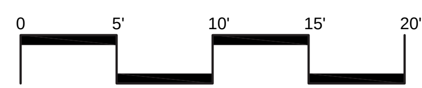
CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT



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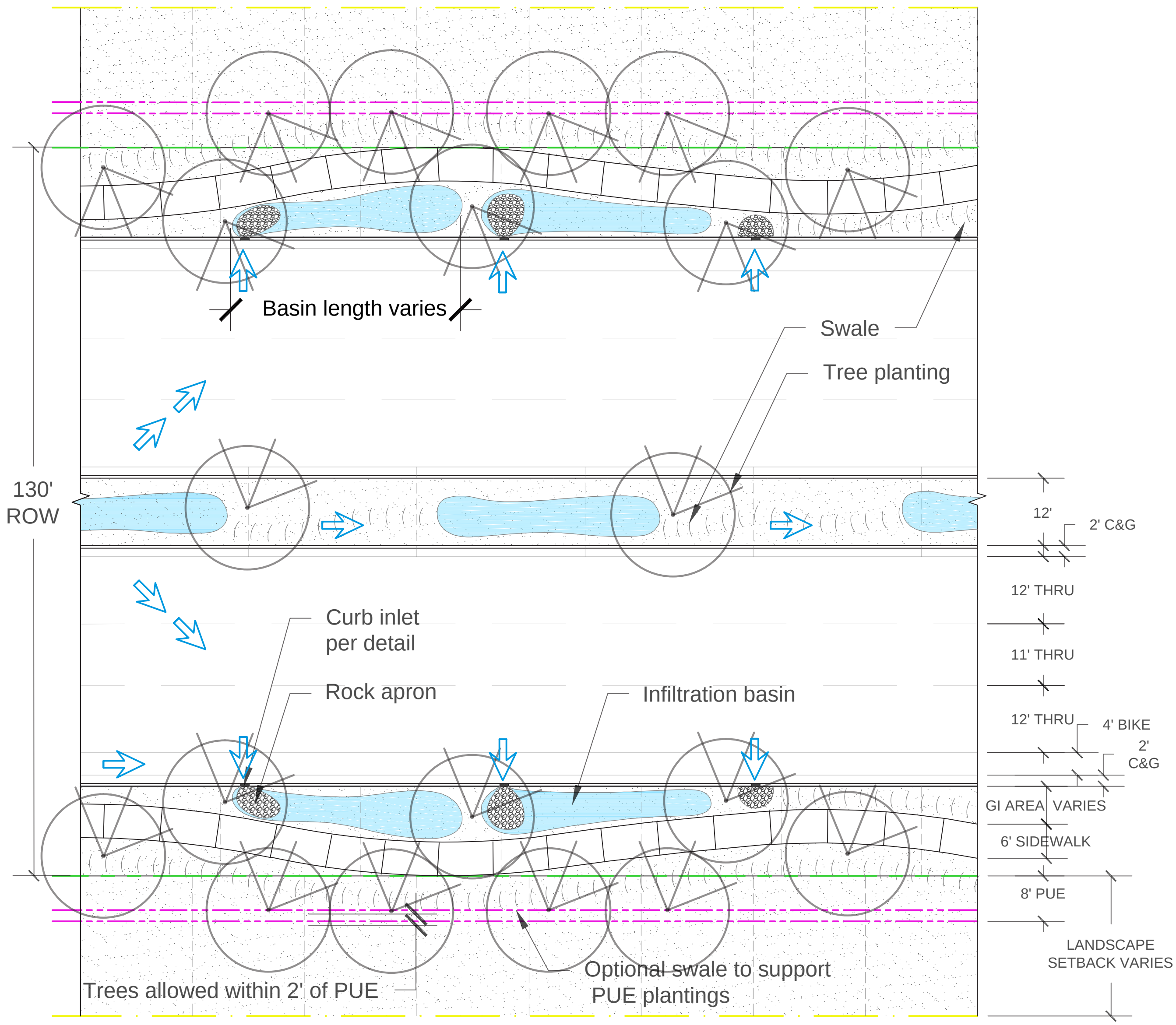

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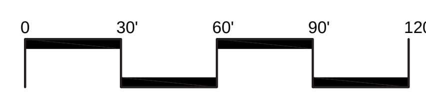
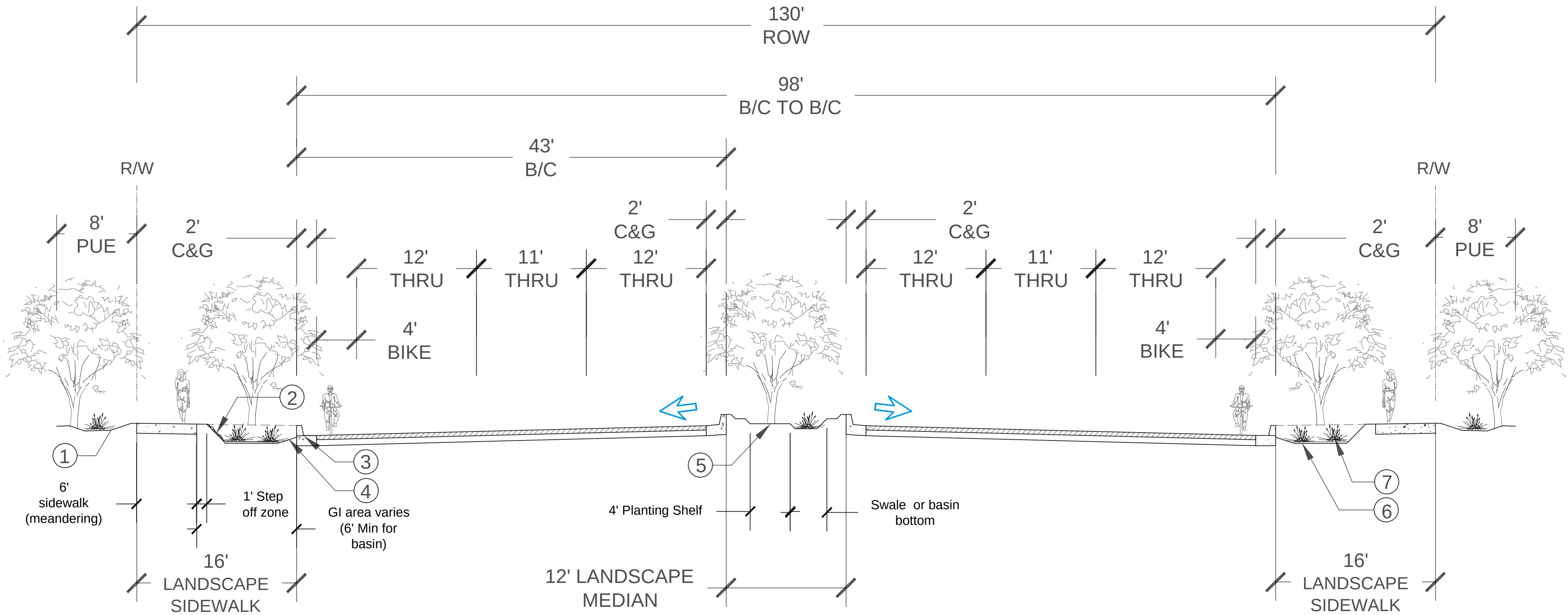
130' ROW GSI INTEGRATION - TYPICAL STREET DESIGN WITH MEANDERING PATH

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT



SCALE 1" = 30'



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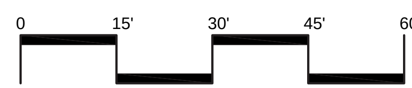
130' ROW GSI INTEGRATION - TYPICAL STREET DESIGN WITH MEANDERING PATH

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT



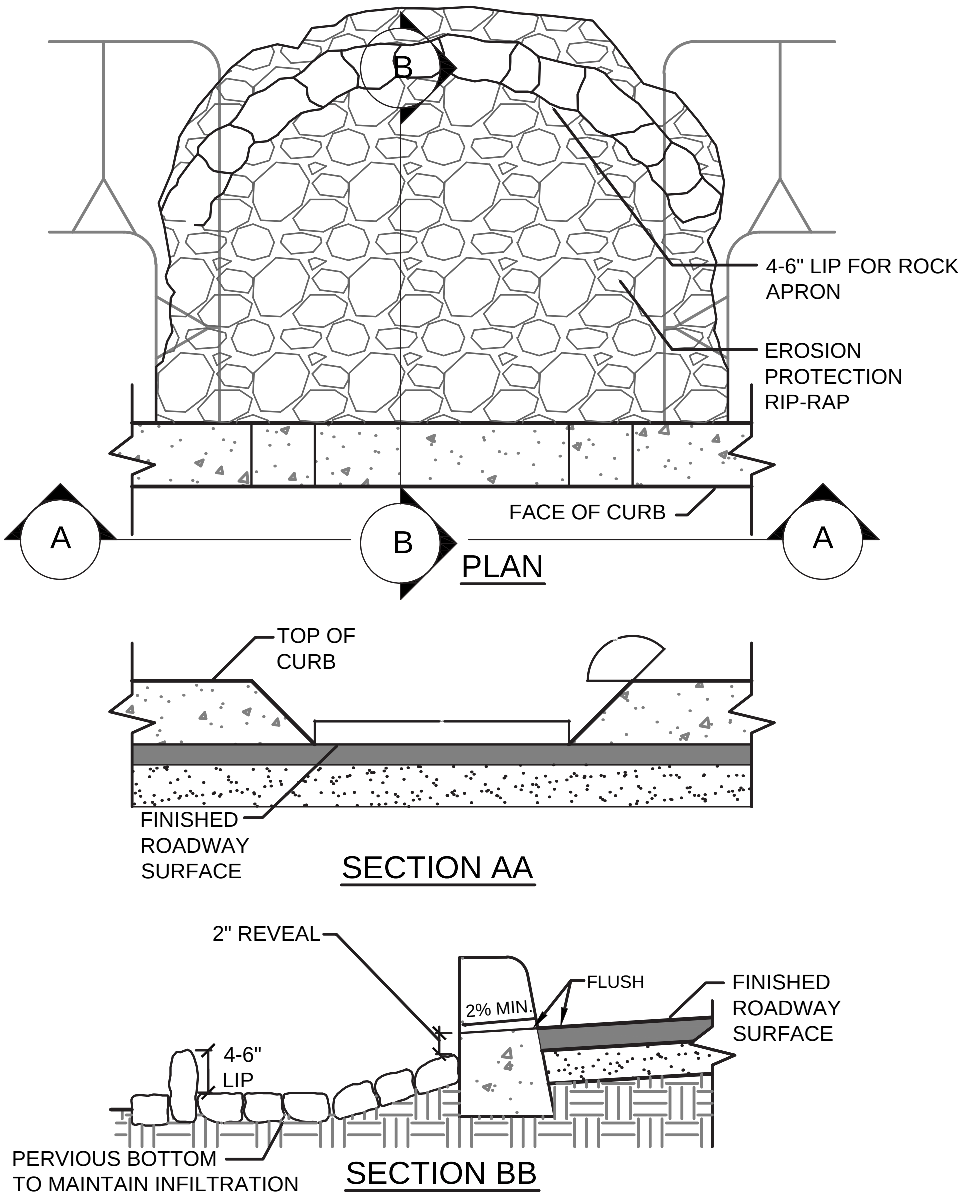
SCALE 1" = 15'

GREEN STORMWATER INFRASTRUCTURE DETAILS

Sources |
Watershed Management Group, Green Infrastructure for Desert Communities
Sustainable Cities Network, Green Infrastructure/ LID Handbook

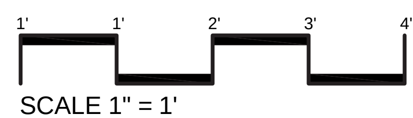
NOTES

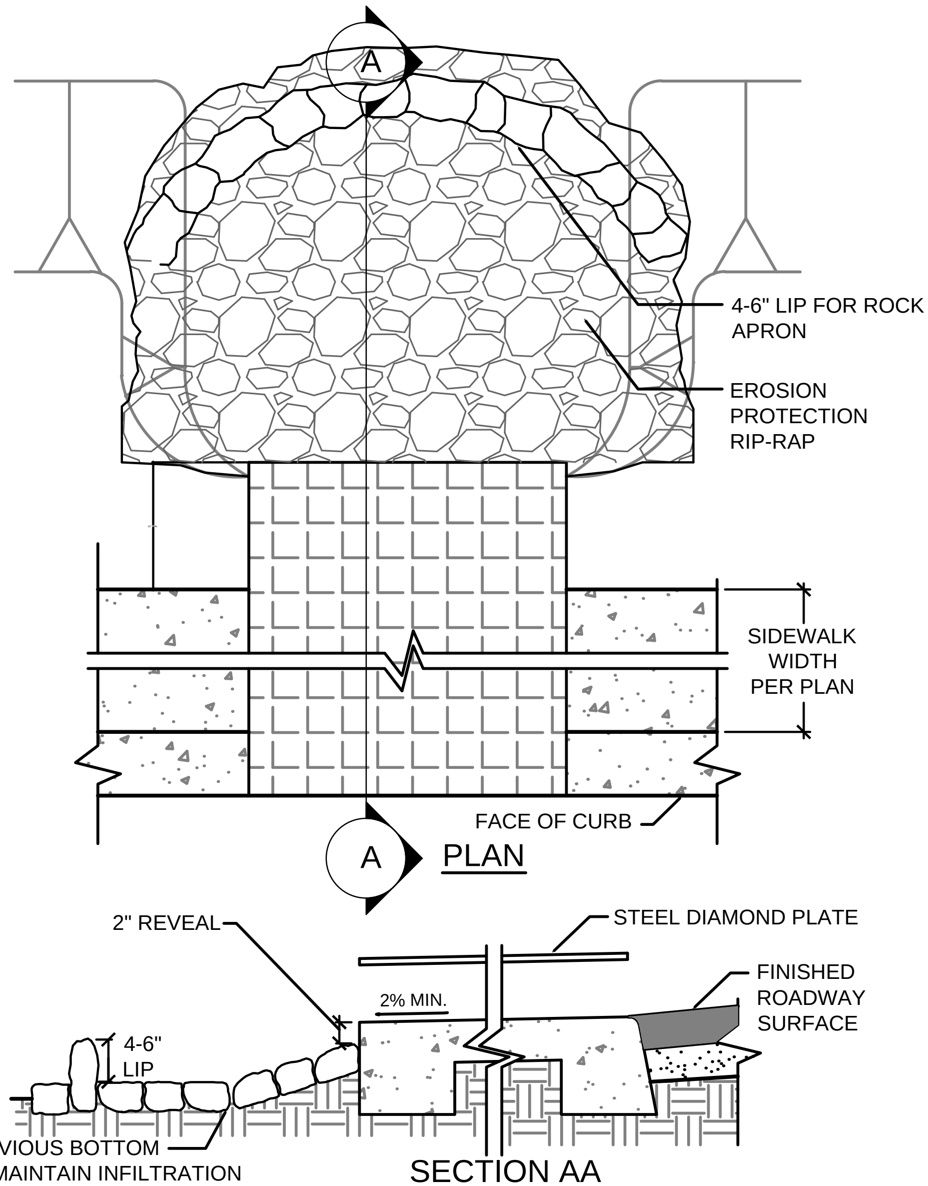
- Details are for reference only and are not to be used for construction purposes
- Maintain a minimum 2" drop from bottom of curb cut to top of soil in order to increase speed of flow into basin and reduce clogging at the inlet due to slow moving water dropping out sediment
- Curb cut shall be on the upstream side of "eddy" (single inlet/outlet) basins to increase basin capacity and prevent mulch from floating out of the basin
- A rip-rap apron should be built where the water flow crosses the curb inlet into the basin. The apron will prevent soil erosion and undercutting of the road surface. Rock sized 4” – 8” can be laid in a single well-fitted course around the entrance. The top of the rock surface should be laid 1 – 2” below the level of the bottom of the curb cut to ensure positive water flow into the basin



GSI DETAILS - CURB INLET WITH ROCK APRON

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT



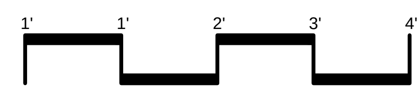


NOTES

- Details are for reference only and are not to be used for construction purposes
- Scuppers are preferred in high-use pedestrian zones and/or when water needs to be conveyed through a non landscaped area (e.g. under a sidewalk)
- Scuppers may be preferred as they require less periodic maintenance to ensure function
- Maintain a minimum 2" drop from bottom of curb cut to top of soil in order to increase speed of flow into basin and reduce clogging at the inlet due to slow moving water dropping out sediment
- Scupper shall be on the upstream side of "eddy" (single inlet/outlet) basins to increase basin capacity and prevent mulch from floating out of the basin

GSI DETAILS - INLET ALTERNATIVE - SCUPPER WITH ROCK APRON

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT



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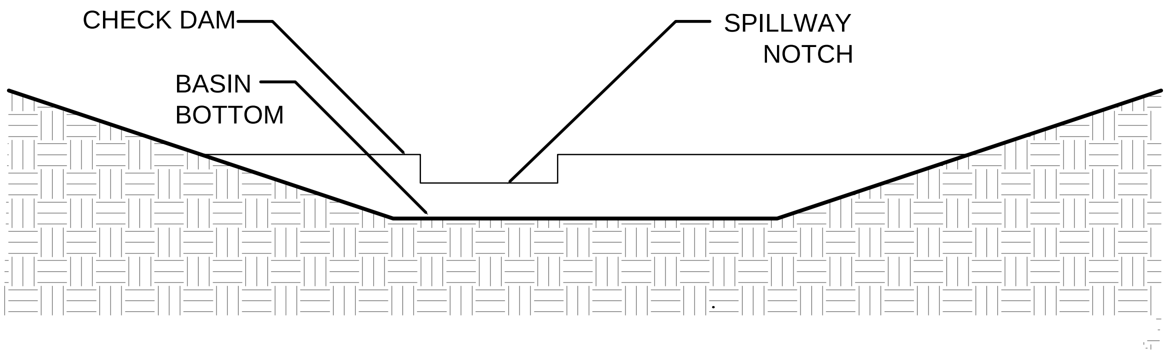
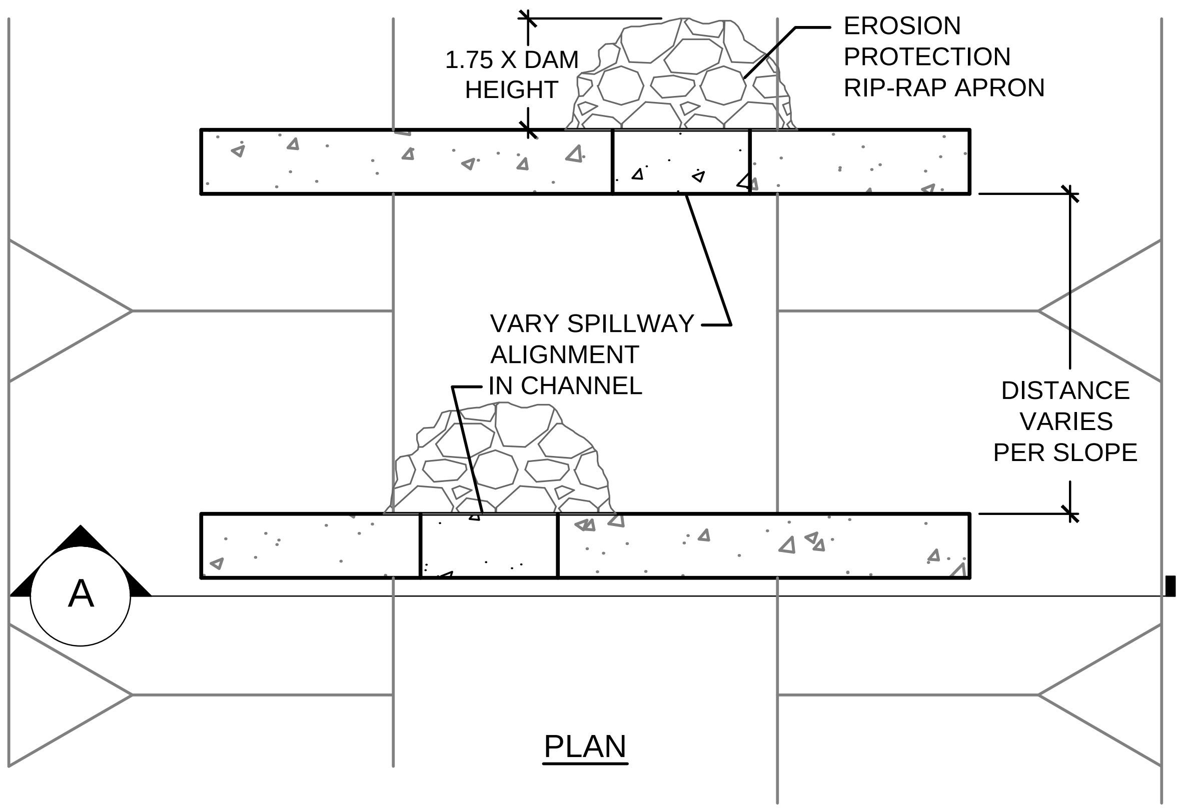


SECTION

NOTES

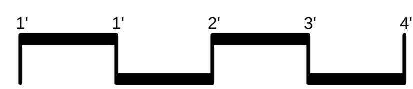
- Details are for reference only and are not to be used for construction purposes
- Locations, width, and distance between checkdams will vary based on slope



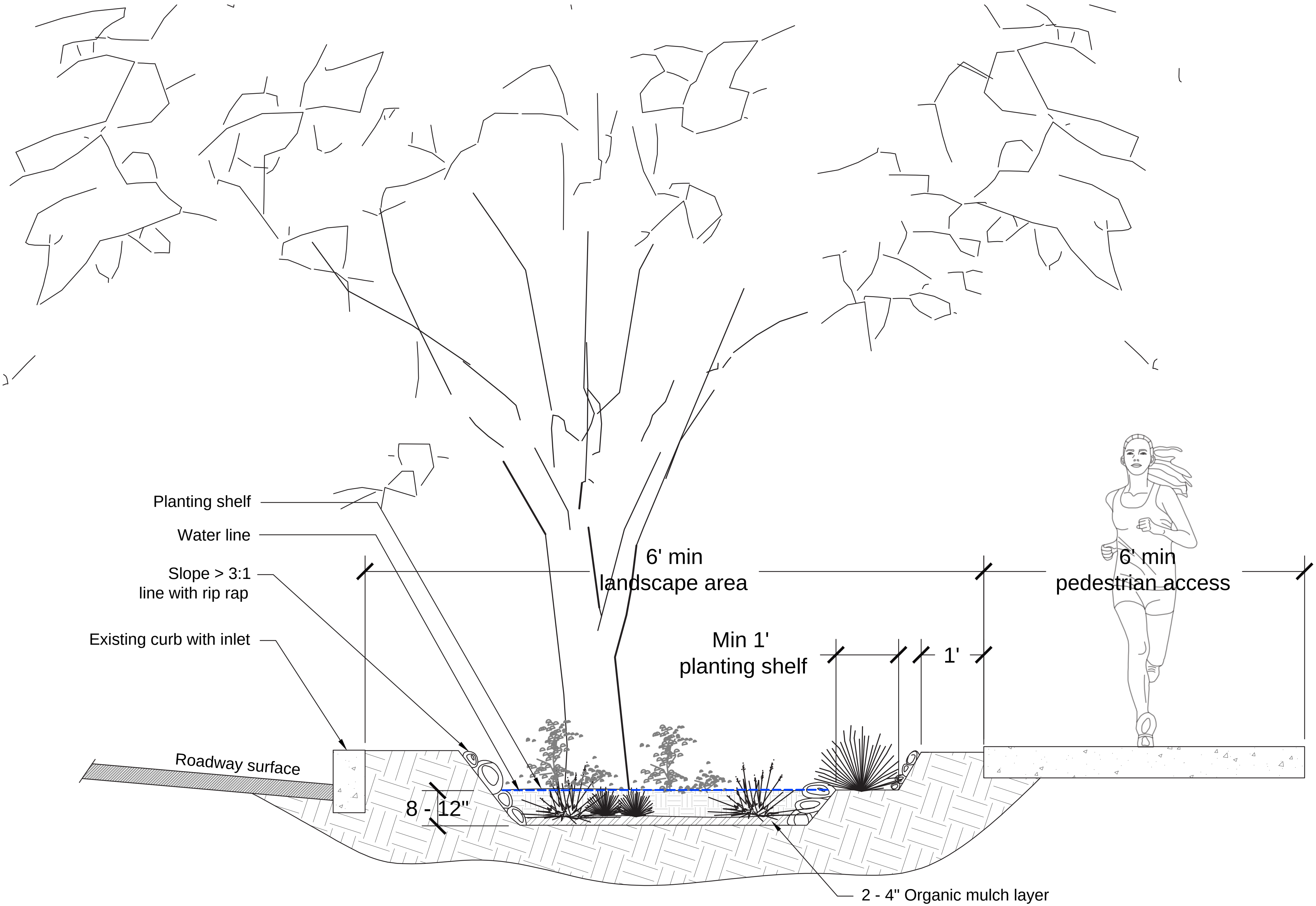
PLAN

GSI DETAILS - MEDIAN SWALE WITH CHECKDAM

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT

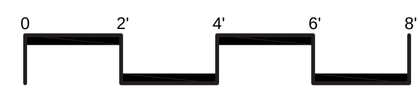


SCALE 1" = 1'

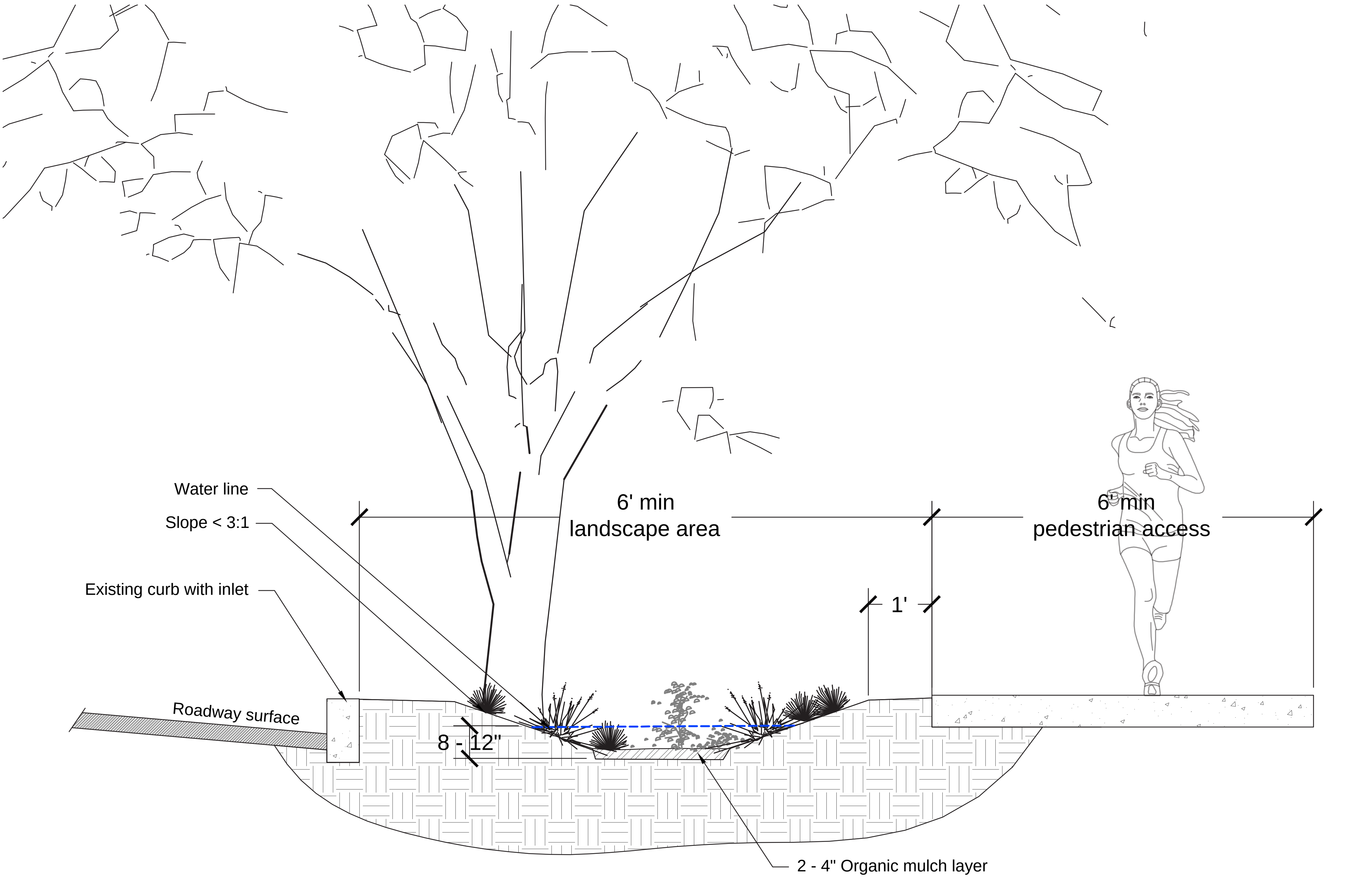


GSI DETAILS - ROADSIDE INFILTRATION BASIN WITH RIPRAP

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT

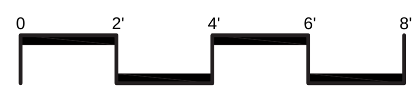


SCALE 1/2" = 1'



GSI DETAILS - ROADSIDE INFILTRATION BASIN WITH RIPRAP

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT



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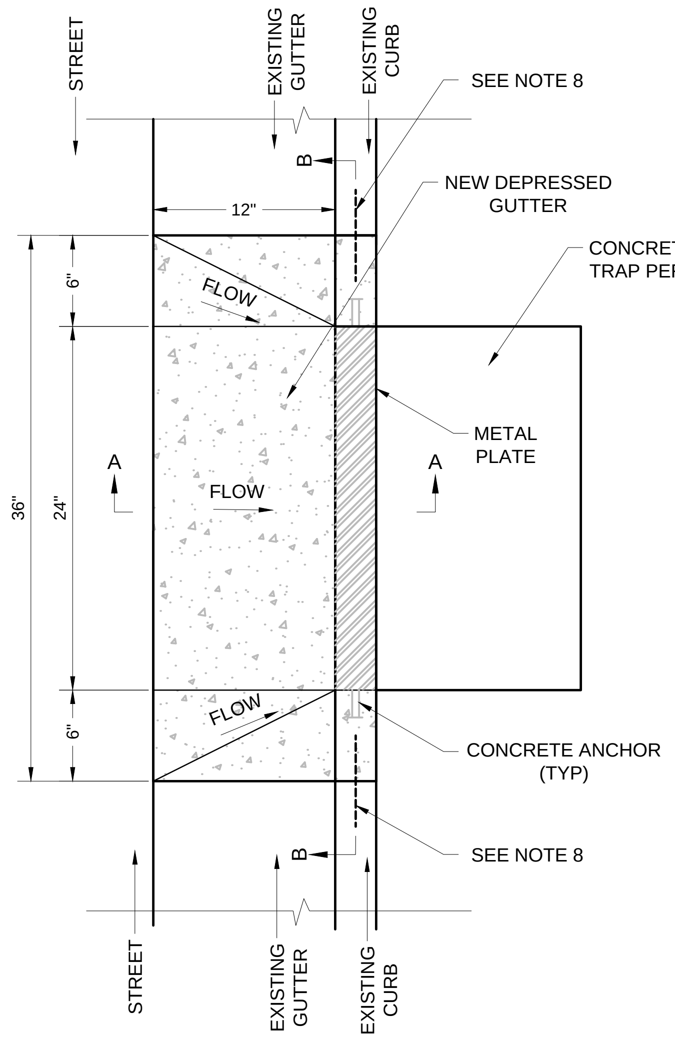
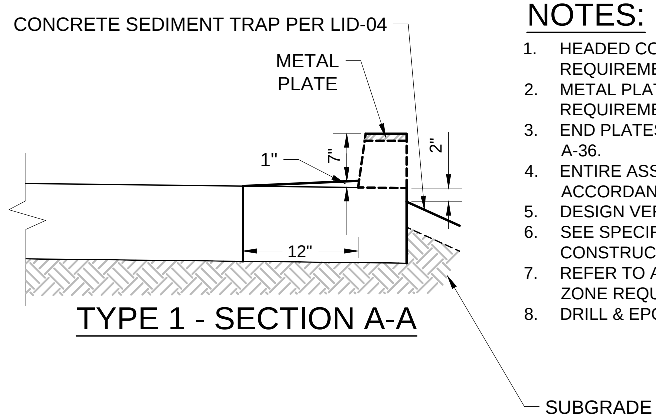


CURB OPENING - TYPE 1

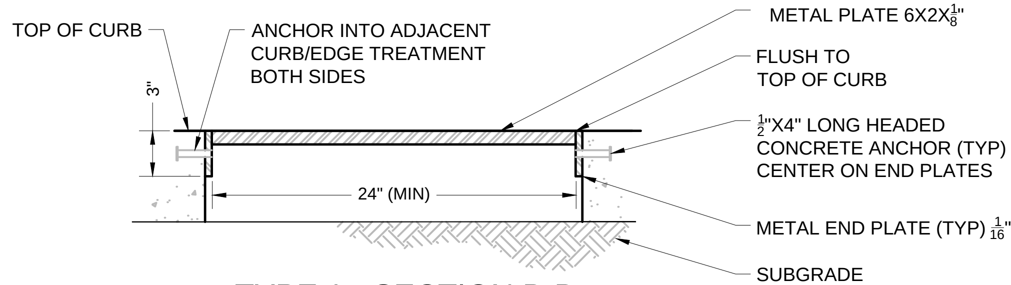
RETROFIT OPENING
WITH VERTICAL CUT



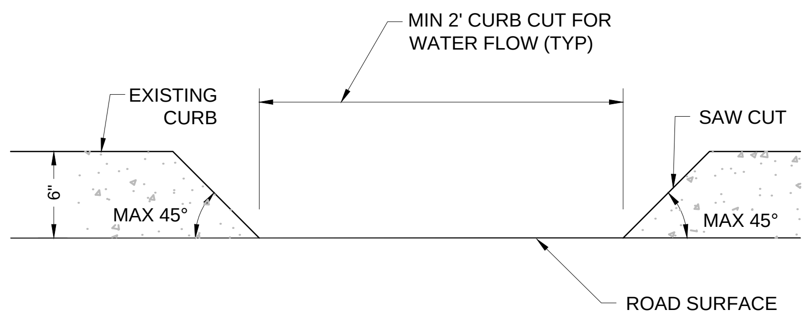
TYPE 1 - SECTION A-A

NOTES:

1. HEADED CONCRETE ANCHORS SHALL MEET THE REQUIREMENTS OF ASTM A-108.
2. METAL PLATE 6X2X1/8 CHANNEL SHALL MEET THE REQUIREMENTS OF ASTM A-500 GRADE B.
3. END PLATES SHALL MEET THE REQUIREMENTS OF ASTM A-36.
4. ENTIRE ASSEMBLY SHALL BE HOT DIP GALVANIZED IN ACCORDANCE WITH ASTM A-123.
5. DESIGN VERTICAL WHEEL LOAD IS 8.5 KIPS.
6. SEE SPECIFICATION 341 FOR MATERIAL AND CONSTRUCTION INFORMATION.
7. REFER TO AASHTO ROADWAY DESIGN GUIDE FOR CLEAR ZONE REQUIREMENTS FOR SPEED DESIGNS.
8. DRILL & EPOXY #4x6"REBAR



TYPE 1 - SECTION B-B



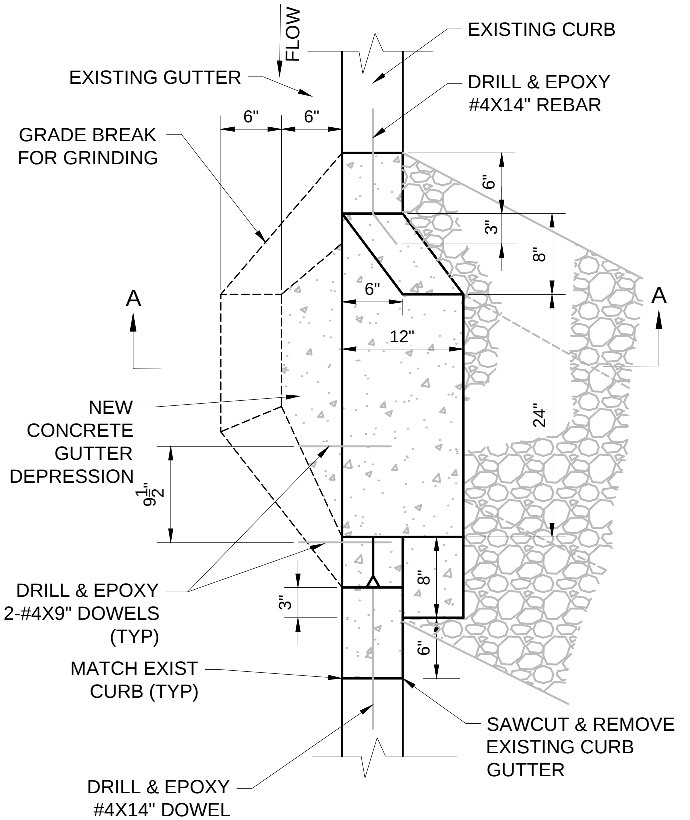
CURB OPENING - TYPE 2

ANGLED CURB CUT

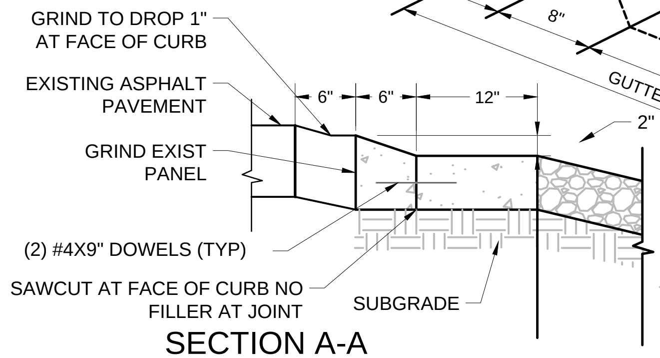
NOTES:

1. DO NOT CUT DEEPER THAN ROAD SURFACE ELEVATION.
2. ALL CURB OPENINGS SHALL BE MADE BY SAW CUT METHOD.
3. GRIND EXPOSED METAL AND SEAL TO PROTECT FROM CORROSION.

DETAIL NO.	STANDARD DETAIL		REVISED	DETAIL NO.
LID-02	ENGLISH	CURB OPENINGS	01-29-2019	LID-02



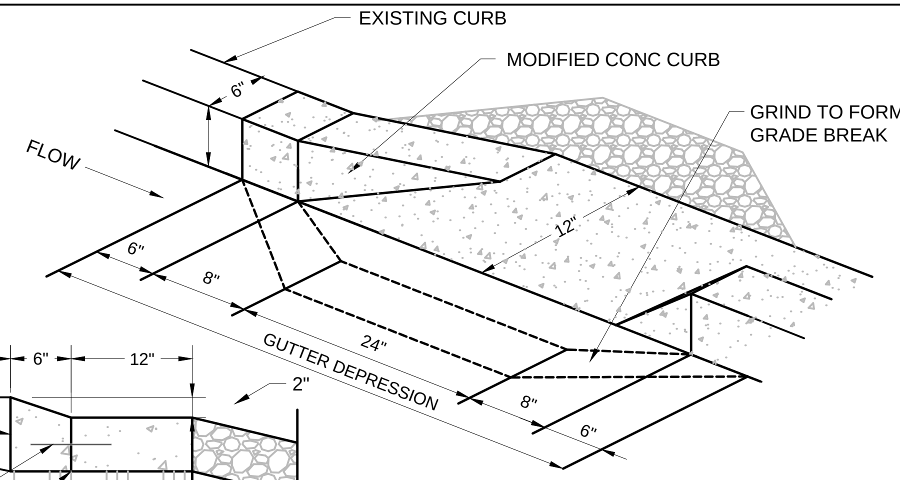
TYPE 3 - PLAN VIEW



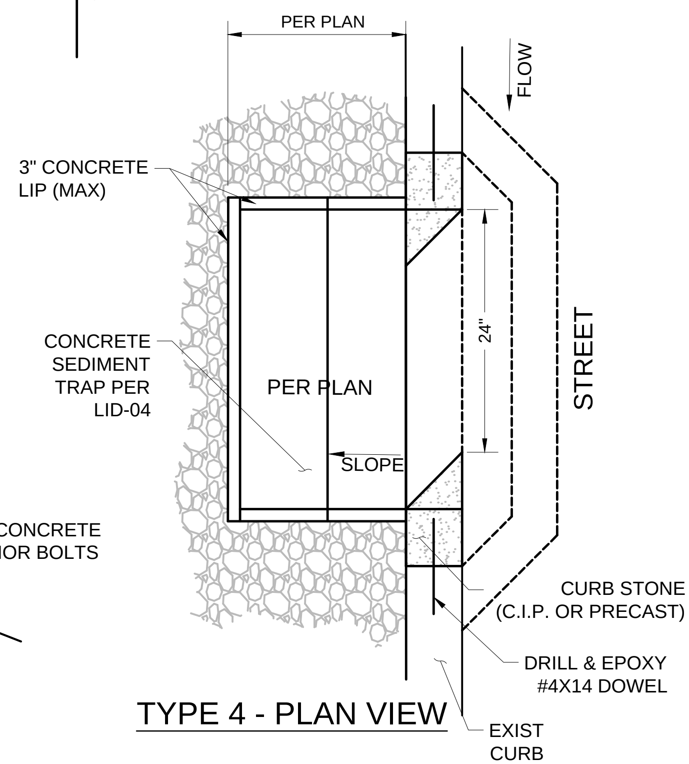
SECTION A-A

CURB OPENING - TYPE 3

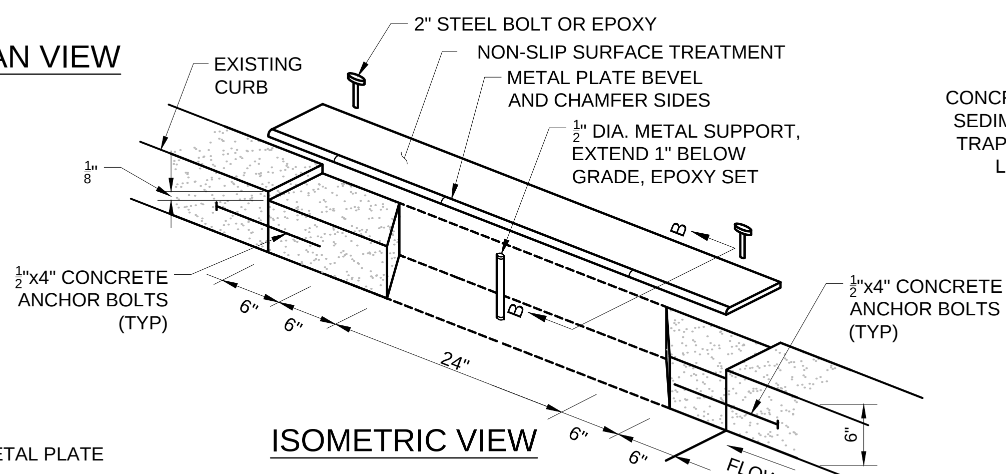
CONCENTRATED FLOW INLET



TYPE 3 -ISOMETRIC VIEW



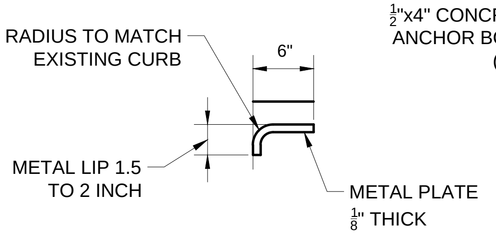
TYPE 4 - PLAN VIEW



ISOMETRIC VIEW

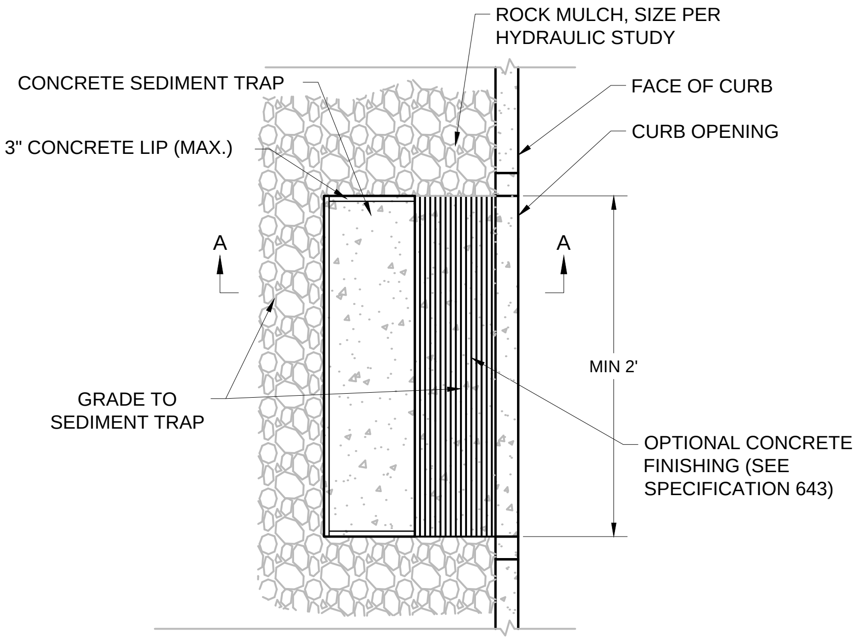
CURB OPENING - TYPE 4

CONCENTRATED FLOW INLET

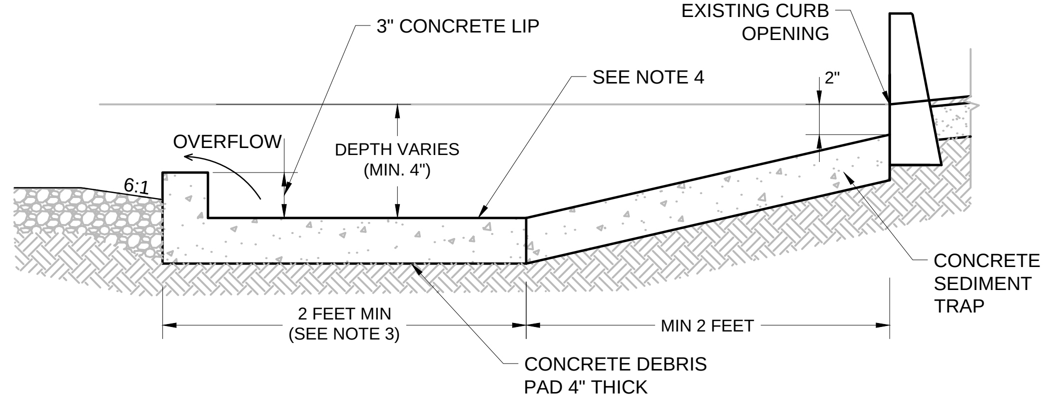


TYPE 4 - SECTION B-B

DETAIL NO.	STANDARD DETAIL ENGLISH	CURB OPENINGS	REVISED	DETAIL NO.
LID-03			01-29-2019	LID-03



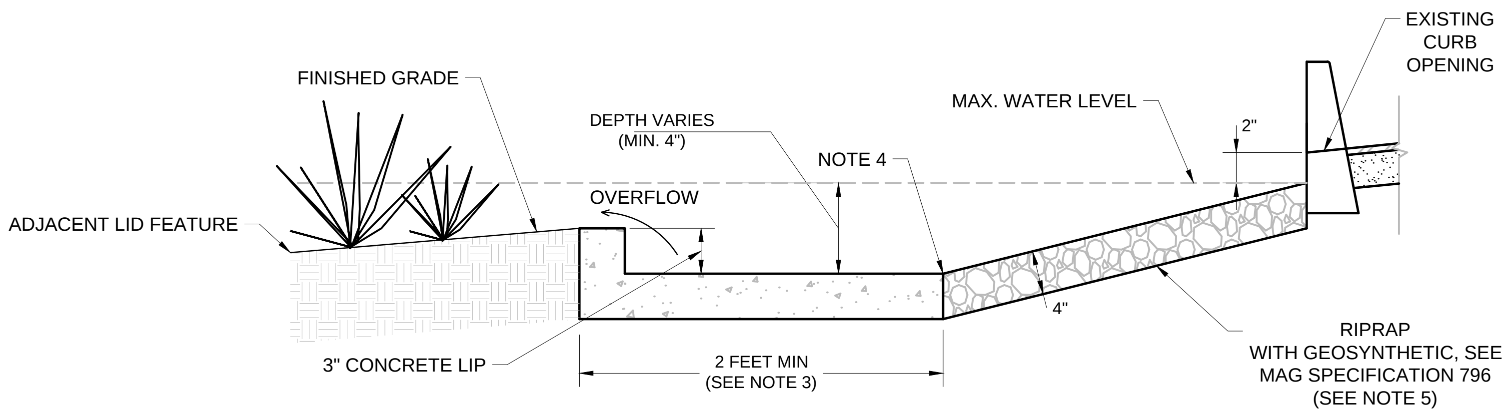
SEDIMENT TRAP PLAN VIEW



SECTION A-A

NOTES:

1. DIMENSIONS OF SEDIMENT TRAP SHOULD BE ADJUSTED BASED ON CONTRIBUTING WATERSHED SIZE AND SEDIMENT LOAD.
2. SEDIMENT TRAP CAN BE PRECAST OR CAST IN PLACE CONCRETE.
3. DEBRIS PAD SHOULD BE DESIGNED TO CONTAIN HYDRAULIC JUMP (IF POSSIBLE).
4. EXPANSION/CONTRACTION JOINT
5. RIPRAP SIZE BASED ON DESIGN REPORT.

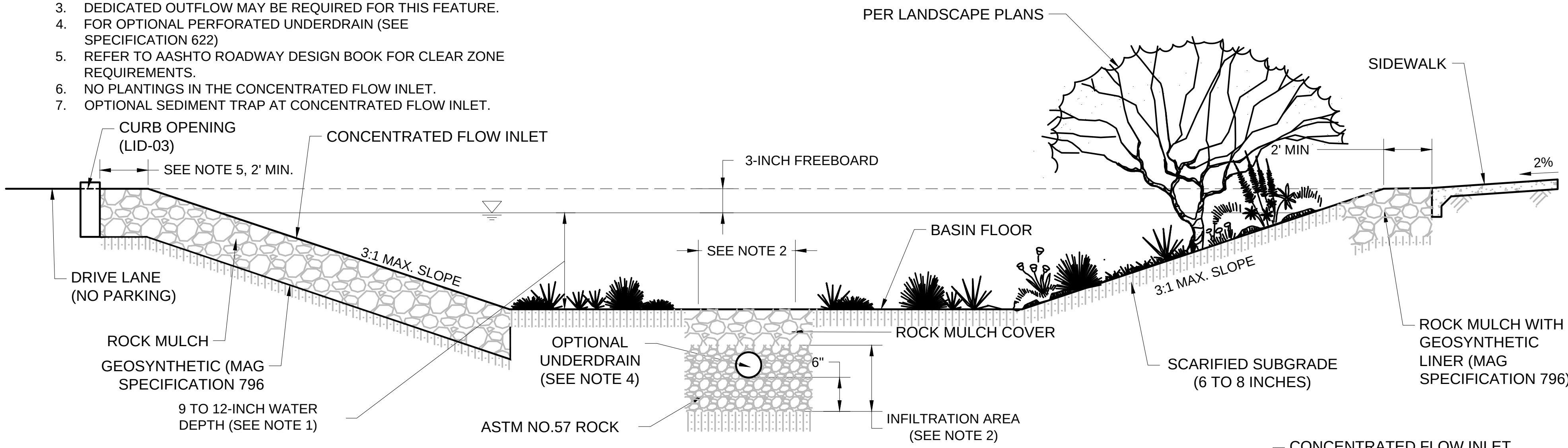


SEDIMENT TRAP WITH RIPRAP SPILLWAY

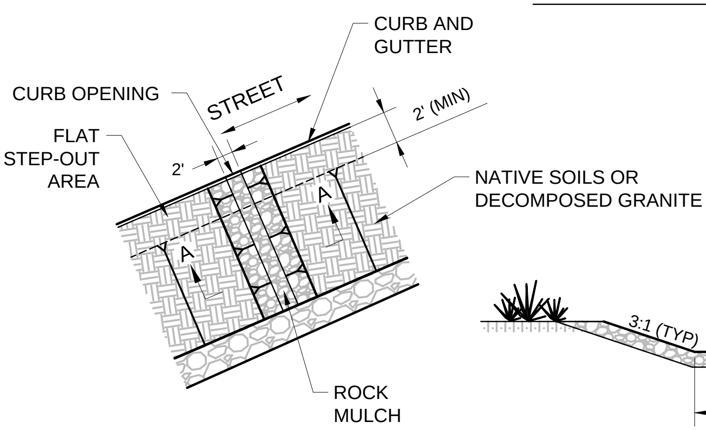
DETAIL NO.	STANDARD DETAIL		REVISED	DETAIL NO.
LID-04	ENGLISH	SEDIMENT TRAPS	01-29-2019	LID-04

GENERAL NOTES (BASIN):

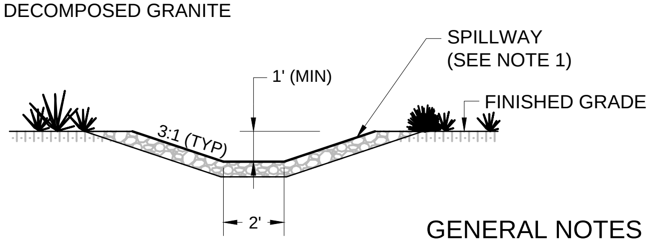
1. SURFACE WATER MUST DRAIN WITHIN 36 HOURS.
2. INFILTRATION AREA DEPTH AND WIDTH DETERMINED BY PERCOLATING WITHIN 72 HOURS. WIDTH MUST EXCEED DEPTH.
3. DEDICATED OUTFLOW MAY BE REQUIRED FOR THIS FEATURE.
4. FOR OPTIONAL PERFORATED UNDERDRAIN (SEE SPECIFICATION 622)
5. REFER TO AASHTO ROADWAY DESIGN BOOK FOR CLEAR ZONE REQUIREMENTS.
6. NO PLANTINGS IN THE CONCENTRATED FLOW INLET.
7. OPTIONAL SEDIMENT TRAP AT CONCENTRATED FLOW INLET.



STORMWATER HARVESTING BASIN SECTION WITH CUT THROUGH CONCENTRATED FLOW INLET



PLAN

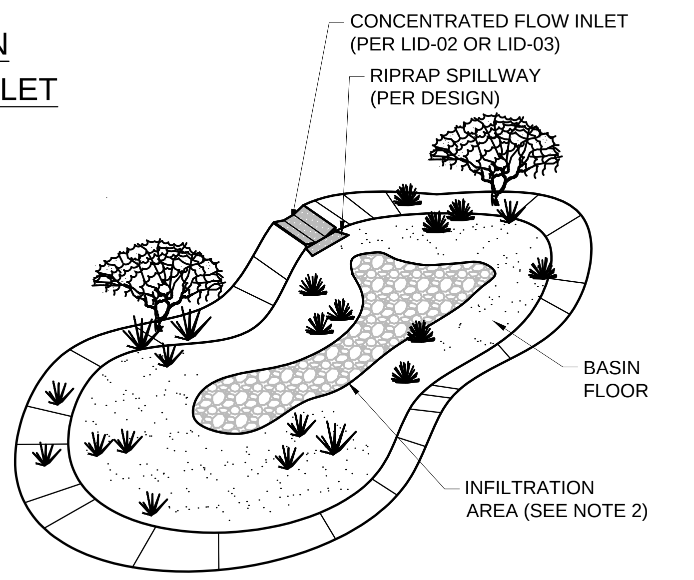


SECTION A-A

GENERAL NOTES (INLET):

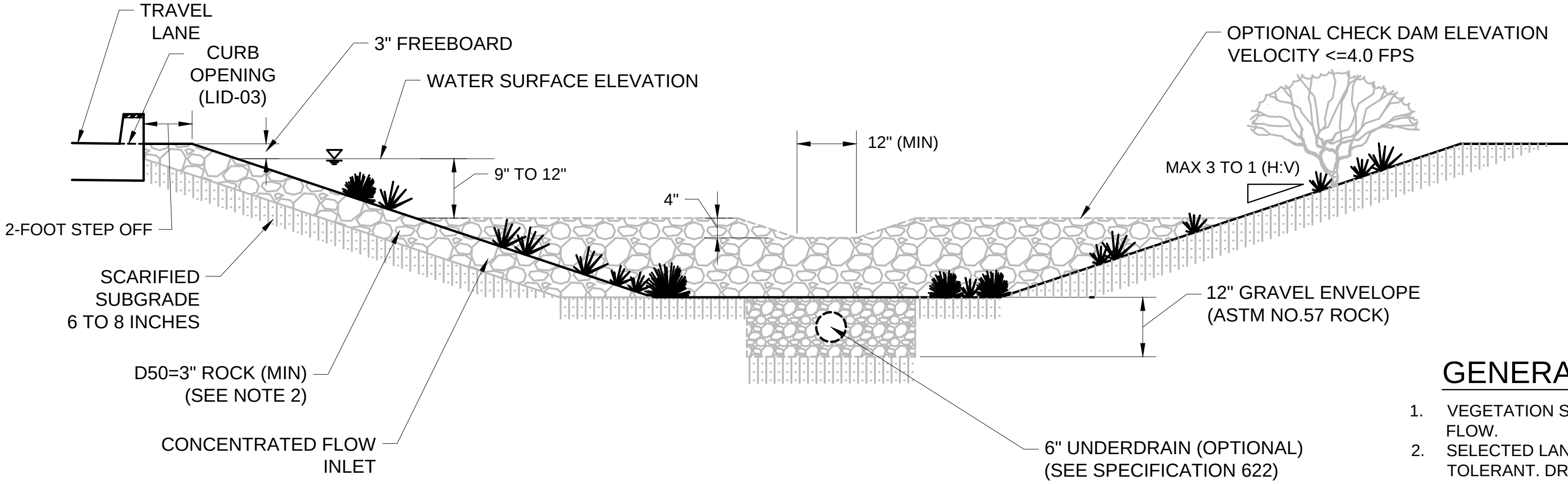
1. SPILLWAY CAN BE 4" THICK CONCRETE TRAPEZOID SCUPPER 6" DEEP OR ROCK SPILLWAY BASED ON DESIGN.

RIPRAP SPILLWAY (PLAN & SECTION)



ISOMETRIC VIEW

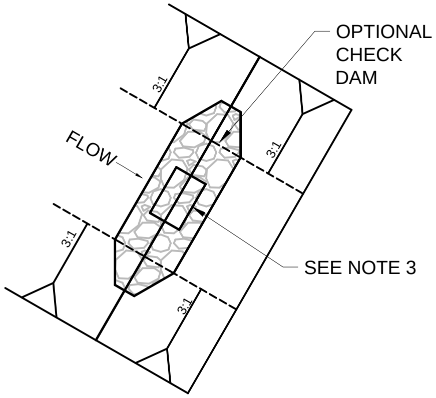
DETAIL NO. LID-05	STANDARD DETAIL ENGLISH	STORMWATER HARVESTING BASINS	REVISED 01-29-2019	DETAIL NO. LID-05



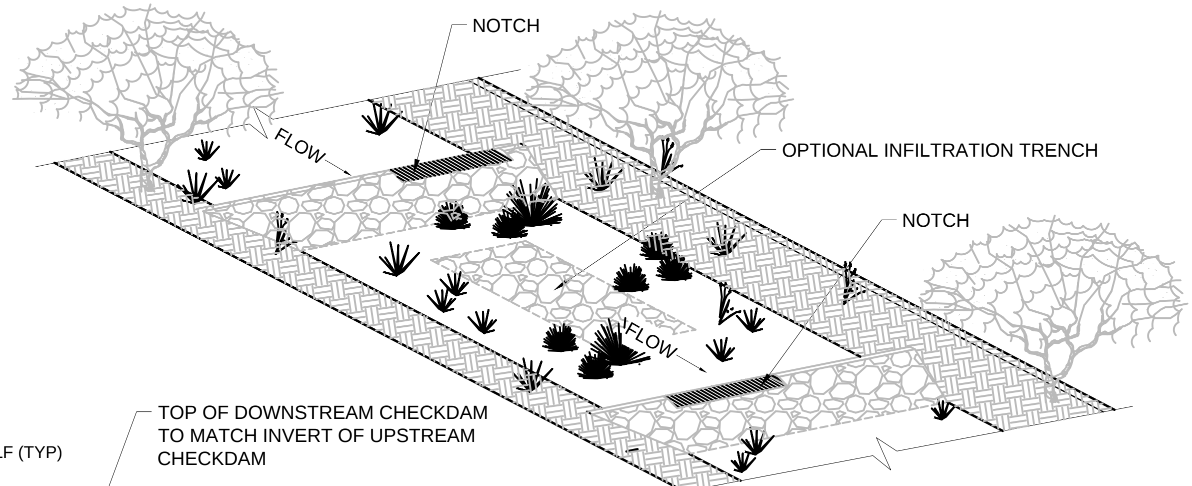
BIOSWALE SECTION

GENERAL NOTES (BIOSWALE):

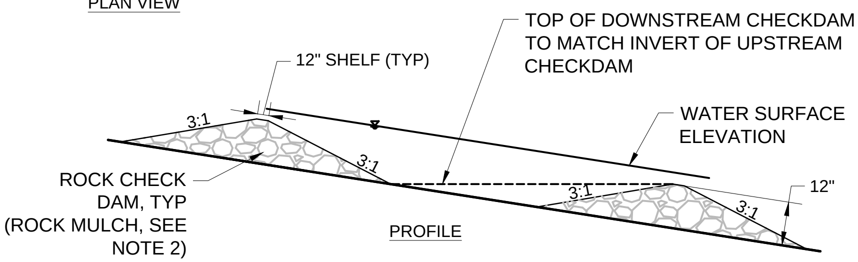
1. VEGETATION SHOULD BE OFFSET FROM CONCENTRATED FLOW.
2. SELECTED LANDSCAPE PLANTS SHOULD BE DROUGHT TOLERANT. DRIP IRRIGATION WILL BE PROVIDED BY A TEMPORARY OR PERMANENT IRRIGATION SYSTEM.



PLAN VIEW



ISOMETRIC VIEW



PROFILE

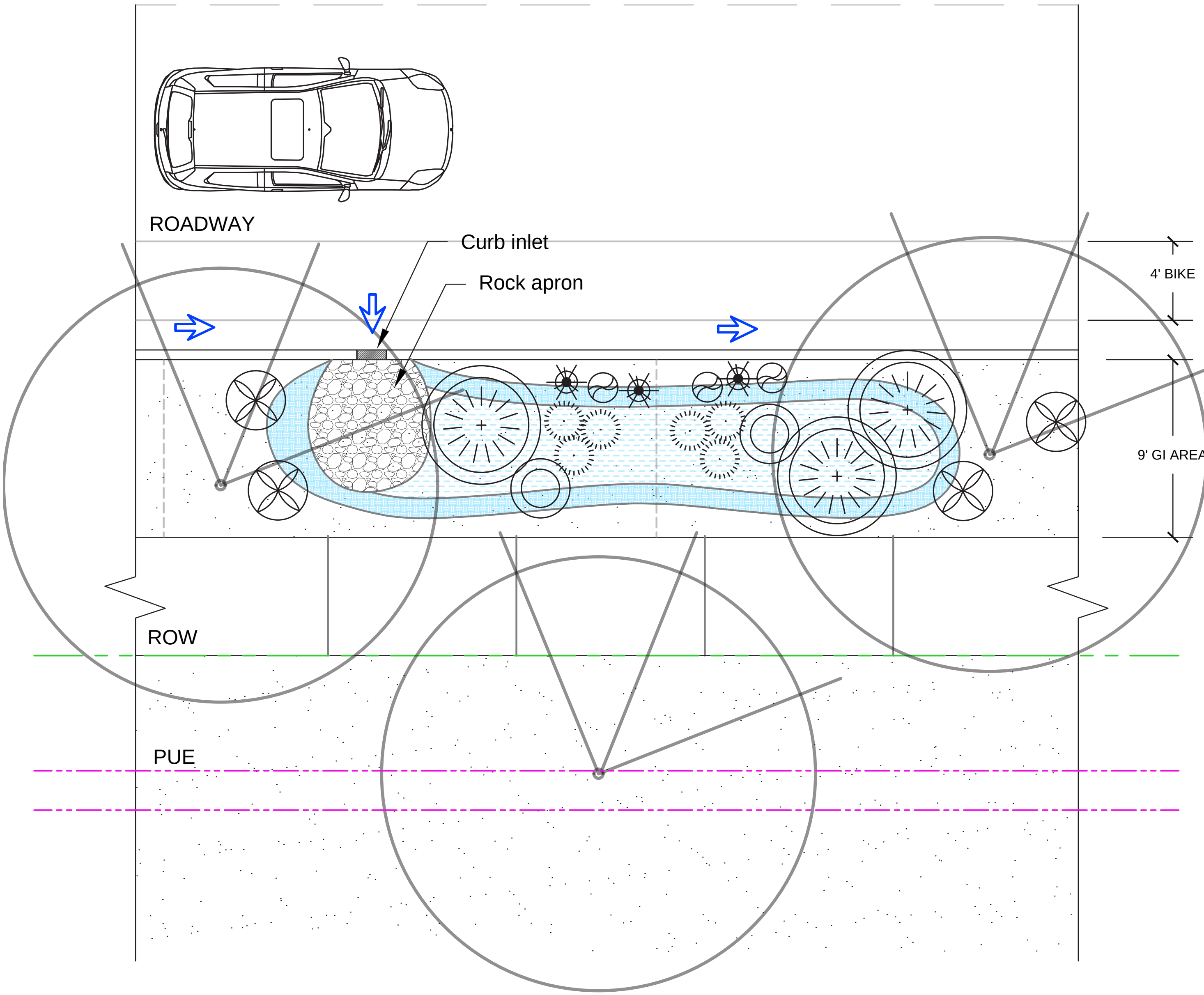
OPTIONAL ROCK CHECK DAM

GENERAL NOTES (CHECK DAM):

1. OPTIONAL CHECK DAM IS MEANT TO DISPERSE DURING HIGHER FLOWS, SEE SECTION 640.3.3 OF SPECIFICATIONS.
2. D50 SIZE DETERMINED BY THE DESIGN REPORT.
3. NOTCHES SHALL BE OFFSET FROM ONE ANOTHER.
4. DEDICATED OUTFLOW REQUIRED FOR THIS FEATURE.
5. OPTIONAL ROCK CHECK DAM TO BE LOCATED TO REDUCE VELOCITIES PER DESIGN REPORT.
6. RIPRAP AND ROCK MULCH REQUIRED WHEN VELOCITIES EXCEED TABLE 6.2 OF THE FLOOD CONTROL DISTRICT OF MARICOPA COUNTY HYDRAULICS MANUAL.

DETAIL NO.	STANDARD DETAIL		REVISED	DETAIL NO.
LID-06	ENGLISH	VEGETATED OR ROCK BIOSWALES	01-29-2019	LID-06

PLANTING PALETTE TYPOLOGIES



PLANT LEGEND

- Feathery Senna *Senna artemesioides*
- Western Mugwort *Artemesia ludoviciana*
- Native Fairy Duster *Calliandra eriophylla*
- Bullgrass *Muhlenbergia emerslyi*
- Desert Milkweed *Asclepias subulata*
- Desert Marigold *Baileya multiradiata*

0 8' 16' 24' 32'

SCALE 1" = 1/8"

ROADSIDE BASIN - PLANTING PALETTE OPTION

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT


Feathery Senna

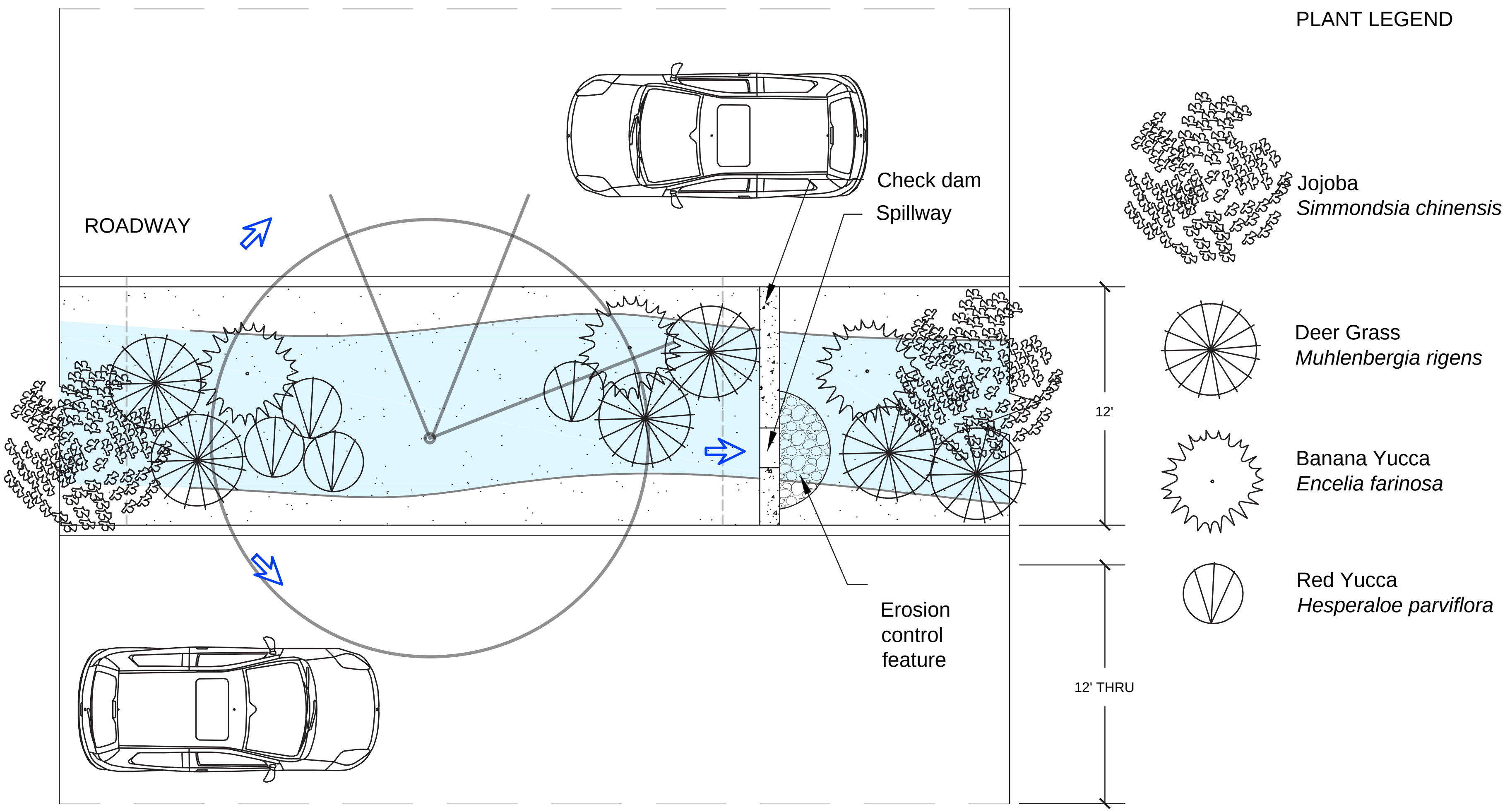

Western Mugwort


Native Fairy Duster


Bullgrass

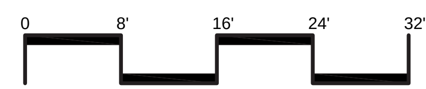

Desert Milkweed


Desert Marigold



12' MEDIAN SWALE - PLANTING PALETTE OPTION

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT



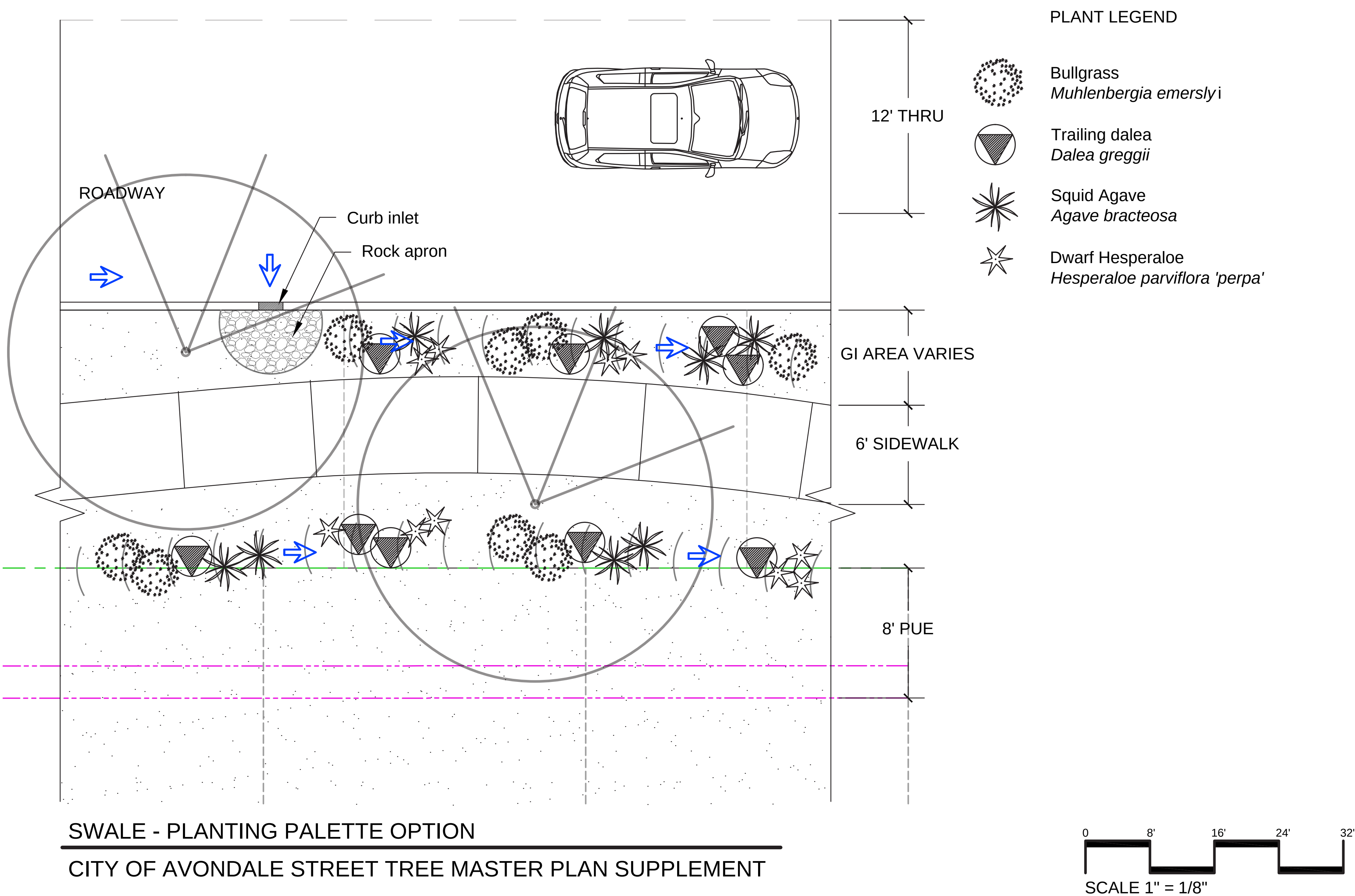
SCALE 1" = 1/8"

Jojoba

Banana Yucca

Deergrass

Red Yucca



SWALE - PLANTING PALETTE OPTION

CITY OF AVONDALE STREET TREE MASTER PLAN SUPPLEMENT


Trailing Dalea


Squid Agave


Bullgrass


Dwarf Hesperaloe

PLANTING PALETTE OPTIONS

Master Street Tree Plan Tree Species

Common	Latin Binomial	Notes
Chinese Elm	*Ulmus parvifolia*	Requires deep irrigation during drought
Evergreen Oak	*Quercus virginiana*	Not recommended due to poor growth experience in City of Avondale
Indian Rosewood	*Dalbergia sisoo*	High water use tree, requires relatively shady, cool microclimate
Mastic Tree	*Pistacia lentiscus*	
Palo Verde	*Parkinsonia spp.*	Diverse species within group, would recommend specific, native, species
Red Push Pistache	*Pistacia x 'Red Push'*	
Sweet Acacia	*Acacia farnesiana*	
Thornless Mesquite Hybrid	*Prosopis x hybrid 'thornless'*	Native species are not thornless; hybrid variety not recommended due to weak structure
Willow Acacia	*Acacia salicina*	
Swan Hill Olive	*Olea europaea 'Swan Hill' Olive*	
Anacacho Orchid	*Bauhinia lunaroides*	
Desert Willow	*Chilopsis linearis*	
Mexican Redbud	*Cercis canadensis var. mexicana*	
Mulga Tree	*Acacia aneura*	
Thornless Cascalote	*Caesalpinina cacalaco*	
Chaste Tree	*Vitex agnus Castus*	
Ghost Gum	*Eucaplyptus papuana*	Highly aggressive root system that can kill / deter understory growth, intolerant of hard frosts
Chitalpa	*Chitalpa tashkentensis*	

Recommended Tree Alternatives

Common	Binomial	Alternative for	Notes
Netleaf hackberry	*Celtis reticulata*	Indian rosewood	For areas with higher irrigation, native alternative, single to multi-trunk
Bottle Tree	*Brachychiton populneus*	Indian rosewood, Willow Acacia, Ghost Gum	Very narrow growth, reflective heat and drought tolerant, can be frost sensitive, single-trunk
Bottlebrush Tree	*Callistemon viminalis*	Accent tree, Red Push pistache	Low water use, near native, single to multi- trunk
Texas Ebony	*Ebonopsis ebano*	Red Push, Olive	Low water use, near native
Ironwood	*Olneya tesota*	Olive	Drought tolerant native, single to multi-trunk, narrow growth form
Featherbush	*Lysiloma watsonii*	Small - Medium tree, or large shrub	Drought tolerant native, multi-trunk
Guajillo	*Acacia Berlandieri*	Small - Medium tree, or large shrub	Drought tolerant native, multi-single trunk
Foothills Palo Verde	*Parkinsonia microphylla*	High water use, or non-native	Drought tolerant native, multi-trunk
Palo Brea	*Parkinsonia praecox*	High water use, or non-native	Drought tolerant native, fast grower, multi-trunk
Catclaw Acacia	*Acacia greggi*	Olive	Drought tolerant native, multi-trunk
Velvet Mesquite	*Prosopis velutina*	Thornless mesquite hybrid	Drought tolerant native, single to multi-trunk

Recommended Mid - Understory Species

All species in the following list are drought tolerant to low water use plants
Planting locations refer to the following:

- Bottom – Refers to bottom of basin. Species that can tolerate inundation
- Edge – Species that need a planting shelf or prefer to be up on the sloped sides of the basin. Species that can tolerate slight inundation
- Out – Species that should not be planted in an area where they will be inundated with water. Species may be planted around the top outside edge of the basin and/or be planted next to and around the basin. Species cannot tolerate inundation
- Anywhere – Species that can tolerate a wide range of inundation conditions and water availability

Common Name	Binomial	Notes	Size (h x w)	Planting location
Grasses				
Side Oats Grama	*Bouteloua curtipendula*	Native, white-gold spikelets	2' x 2'	Bottom
Blue Grama	*Bouteloua gracilis*	Native, unique white-gold spikelets	2' x 2'	Bottom
Bullgrass	*Muhlenbergia emersleyi 'El Toro'*	Large white fluffy spikelets	3' x 3'	Bottom
Pink Muhly	*Muhlenbergia 'Regal Mist'*	Large pink fluffy spikelets	3' x 4'	Bottom
Deer Grass	*Muhlenbergia rigens*	Native, narrow tan spikelets	3' x 5'	Bottom
Purple Muhly	*Muhlenbergia rigida*	Native, purple spikelets	2' x 2'	Bottom

Perennial Wildflowers				
Globe Mallow	*Sphaeralcea sp. (typically ambigua, also laxa or others)*	Native, bright orange - pink flowers	1’ to 3' X 1’ to 4'	Anywhere
Desert Marigold	*Baileya multiradiata*	Native, bright yellow flowers	1’ to 2' x 1’ to 3'	Anywhere
Firecracker Penstemon	*Penstemon eatonii*	Native, bright red flowers, pollinator	1’ to 3' X 1’ to 4'	Anywhere
Parry Penstemon	*Penstemon parryi*	Native, bright pink flowers, pollinator	1’ to 3' X 1’ to 4'	Anywhere
Dogweed	*Thymophylla pentachaeta*	Yellow flowers, excellent groundcover	1' x 1'	Anywhere
Desert Senna	*Senna covesii*	Native, bright yellow flowers	1 ' X 1’ to 4'	Anywhere
Flattop Buckwheat	*Eriogonum fasciculatum*	Native	2' x 2'	Anywhere

Groundcovers				
Trailing lantana	*Lantana montevidensis*	Purple flowers	1' to 3’ to 5'	Out / Edge
Lemon Dalea	*Dalea capitata*	Delicate texture, unique yellow flowers, lemon scent	8" x 1’ to 3'	Edge
Trailing Indigo Bush	*Dalea greggii*	Delicate texture, purple flowers	1' to 3’ to 5'	Edge / Out
Damianita	*Chrysactinia mexicana*	Bright yellow flowers	2' x 2'	Bottom / Edge
Dwarf Ruellia	*Ruellia brittoniana 'Katie'*	Large purple flowers	6" x 1’ to 2'	Bottom / Edge

Shrubs				
Prairie acacia, Fern Acacia	*Acacia angustissima*	Near native, fluffy cream flowers, delicate foliage	4' x 4'	Out
Red Bird of Paradise	*Caesalpinia pulcherima*	Near Native, unique red - orange flowers	8' x 8'	Out
Mexican Bird of Paradise	*Caesalpinia mexicana*	Near Native, unique yellow flowers, can be trimmed into small tree	10’ to 15' x 15’ to 15'	Edge / Out
Pink Fairy Duster	*Calliandra eriophylla*	Native, fluffy pink flowers, prolific bloomer	3' x 3'	Out
Turpentine Bush	*Ericameria laricifolia*	Native, fluffy yellow flowers, prolific bloomer	3' x 3'	Out
Blue Emu Bush	*Eremophila hygrophana*	Large blue flowers	2' to 3' x 3' to 4'	Edge / Out
Valentine Emu Bush	*Eremophila maculata 'valentine'*	Large red flowers	2' to 3' x 3' to 4'	Edge / Out
Chuparosa	*Justicia californica*	Native, bright coral flowers, pollinator	3' x 4'	Out / Edge
Desert Ruellia	*Ruellia brittoniana*	Near native, large purple flowers	3' to 6' x 3' to 6'	Bottom / Edge
Dwarf Bottlebrush	*Callistemon viminalis 'little john'*	Unique red fluffy flowers	3' x 5'	Edge
Brittlebush	*Encelia farinosa*	Native, bright yellow flowers, prolific bloomer	3' to 5' x 3 to 7'	Out
Creosote	*Larrea tridentata*	Native, yellow flowers, habitat species	5' x 6'	Out
Goldeneye	*Bahiopsis parishii*	Native, bright yellow flowers, prolific bloomer	3' x 3'	Bottom / Edge
Indian Mallow	*Abuliton palmeri*	Native, orange flowers	5’ x 5’	Out
Shrubby Senna	*Senna wislizeni*	Native, bright yellow flowers, prolific bloomer	5' x 6'	Out / Edge

Shrubs Continued......

Western Mugwort	*Artemesia ludoviciana*	Textural, upright growth form	3' to 6' x 1' to 2'	Anywhere
Hopbush	*Dodonaea viscosa*	Native, lush green, upright growth	12' x 12'	Out / Edge
Wolfberry	*Lycium sp. (fremontii or other)*	Excellent habitat species, edible	8’ x 8’	Edge
Flame Aniscanthus	*Aniscanthus quadrifidius*	Native, bright red flowers, pollinator	3' x 4'	Bottom / Edge
Arizona Rosewood	*Vauquelinia californica*	Native, upright narrow growth	5' to 15' x 10' to 20'	Out / Edge
Giant Hesperaloe	*Hesperaloe funifera*	Upright narrow growth	5' x 5'	Out
Feathery Senna	*Senna artemesioides*	Near native, delicate texture, yellow flowers	6' x 6'	Anywhere
Desert Hackberry	*Celtis pallida*	Native, excellent habitat species	10’ x 10’	Out
Jojoba	*Simmondsia chinensis*	Native, habitat species, edible	5' to 8' x 5' to 8'	Edge / Out
Texas Ranger	*Leucophyllum frutescens*	Native	5' to 8' x 5' to 8'	Out
Chihuahuan Sage	*Leucophyllum laevigatum*	Native	5' to 8' x 5' to 8'	Out

Accents / Succulents				
Dwarf Elephant Food	*Portulacaria afra minima*	Evergreen succulent foliage	1’ x 4’	Anywhere
Beargrass	*Nolina microcarpa*	Native, curly growth form	3' x 5'	Out
Smooth Agave	*Agave desmettiana*	Pollinator,	3' x 3'	Out
Blue Elf Aloe	*Aloe 'blue elf'*	Pollinator, unique coral flowers	1' x 1'	Edge / Out
Medicinal Aloe	*Aloe barbadensis*	Pollinator, unique yellow flowers	1' x 2'	Edge / Out
Coral Aloe	*Aloe striata*	Pollinator, unique coral flowers	2' x 3'	Edge / Out
Peruvian Apple Cactus	*Cereus peruvianus*	Near Native, edible	8' x 12'	Out
Dwarf Hesperaloe	*Hesperaloe parviflora 'perpa'*	Near Native, bright red flowers, pollinator, prolific bloomer	1' x 1'	Out
Soaptree Yucca	*Yucca elata*	Native, large creamy flowers	8' x 12'	Out
Desert Spoon	*Dasylirion wheeleri*	Native, curly growth form	9' x 9'	Out
Toothless Desert Spoon	*Dasylirion quadrangulatum*	Native, delicate textural form	9' x 9'	Out
Santa Rita Prickly Pear	*Opuntia santa rita*	Native, purple body, showy yellow flowers	2' x 2'	Out
Beavertail Prickly Pear	*Opuntia basilaris*	Native, blue-gray body, showy pink flowers	2' x 2'	Out
Texas Prickly Pear	*opuntia engelmannii*	Near native, showy yellow flowers	5' x 5'	Out
Staghorn Cholla	*Cylindropuntia versicolor*	Native, purple body, showy yellow flowers	6 ' to 8' x 6' to 8'	Out
Desert Milkweed	*Asclepias subulata*	Native, pollinator and habitat species, unique cream flowers	2' x 3'	Anywhere
Banana Yucca	*Yucca bacata*	Native, pollinator species, unique cream flowers	5' x 5'	Out

Accents / Succulents Continued......

Ocotillo	*Fouquieria splendens*	Native, drought deciduous, upright narrow growth form, unique red-orange flowers	10’ x 4’	Out
Saguaro	*Carnegia gigantea*	Native, vertical growth form, large cream flowers, habitat and pollinator species	10’ x 8’	Out
Candelilla	*Euphorbia antisyphilitica*	Compact growth form	2' x 2'	Out
Parry's Agave	*Agave parryi*	Native, compact, clustering growth form	2' x 2'	Out
Ocahui Agave	*Agave ocahui*	Near Native, Compact growth form	2' x 2'	Out
Squid Agave	*Agave bracteosa*	Curly growth form	2' x 2'	Out
Shark Skin Agave	*Agave americana*	Gray-green body, large sculptural form	3’ x 4’	Out
Blue Yucca	*Yucca rigida*	Near native	12’ x 8’	Out
Shindagger Agave	*Agave lechuguilla*	Native	2' x 2'	Out