Case Study 1
Water Plan – SR 51 – Shea Blvd. to Bell Rd. (NB & SB)

Freeways in the metro-areas of Phoenix, Arizona have been irrigated by drip irrigation since 1976. What's more, they have been centrally controlled and networked through 700 and 450 MHz radios, and desktop computers. As forward thinking as it was at the time, the systems are managed like electronic timers. This is the view of Rick Young, Jr., who has studied irrigation management methods and systems and is a former ADOT District Landscape Coordinator. "The problem", says Rick, "is that most of the power and capabilities of the software and hardware are not being used. Irrigation is applied on every mile just about the same, which ranges from 5 hours to 25 hours per month on the trees, and 2 hours to 16 hours per month on the shrubs. This may be alright in many cases, but it is out of convenience, not science!"

Outer Loop Highway Landscape Design Guidelines

Sometime in 1985, De Leuw, Cather & Company, the Outer Loop management consultant to the Arizona Depart of Transportation, was tasked to develop landscape design guidelines. The design objective presented in the 1986 publication range from general to specific; such is the nature of modern, manmade landscapes along desert, urban roadways. Directed at landscape architects, the publication covered the design objective for a 55-mile freeway spanning the northern half of the Phoenix metro area, including routing through Scottsdale, Peoria, Glendale, Phoenix, Tolleson, the Salt River Pima Maricopa Indian Community and Avondale.

There are many interesting aspects of the Guideline, covering such topics as plant species selection, grade contouring, planting practices, erosion control, irrigation systems, and graphic standards. One notable requirement is the one requiring the Landscape Architect to provide irrigation schedules. This is interesting because each municipality that had freeway segments provided the water at no cost to ADOT. Through a Master Inter-governmental Agreement, ADOT was responsible for design, construction, and most of the landscape maintenance.

A brief sampling of design and construction budgets, per mile, both sides, in the 2006 and 2007 amounted to $255,000 and $800,000, respectively. Landscape maintenance costs have ranged from $35,000 per mile per year, to $55,000 per mile per year since 1997. The irrigation controller typically installed to handle one-mile segments costs the State $40,000. It is capable of supporting soil moisture sensors and fertilizer injectors, and includes software that could be used to irrigate volumetrically, the highest modes in water management.

Though irrigation-related water costs or energy costs have been marginalized, commercial water rates in Mesa, AZ in 2003 were around $480.00 per acre foot. So these are lost revenue opportunity costs bore by the respective municipality. The water is usually potable water, and provided at pressures in the area of 55 psi. By 2003, only two municipalities were in a position to provide Class III reclaimed water, but pressure at which it is provided is often much lower. Most cities deliver their reclaimed water to the Palo Verde Nuclear Generating Plant 60 miles to the west for cooling of radiation cores, selling it through some formula.

Ground Water Management Planning in Arizona

Since 1985 issuance of the First Management Plan by the Arizona Department of Water Resources (ADWR), water use in the critical groundwater resources areas of Arizona has been regulated. Conservation efforts are required to begin a change in resource management practices, and thus reverse the existing trend towards more and more groundwater mining. Agricultural water use, and irrigation of crops, including orchard and woody shrubs like cotton, comprises over 60% of the water consumed in these areas. Irrigation efficiency norms were established requiring farmers to move towards holding irrigation efficiencies to between 60% and 85%.

In the First Management Plan (FMP) (1980-1990), irrigation efficiency in agriculture, as defined in Arizona, is defined as:

$$\text{Irrigation Efficiency} = \frac{\text{Total Irrigation Requirement}}{\text{Total Volume of Water Applied}}$$

The norms of “Total Water Requirement” were determined for agriculture through multiple years of irrigation treatments and consumptive use accounting by numerous university researchers across Arizona on all of the normally grown crops. For example, the total irrigation requirement (per growing season) for cotton in Arizona was determined to be 3.43 acre feet /acre. Alfalfa, which is well known to increase yields linearly in conjunction with water and heat-units, was allocated 4.33 AF/Ac for the historic state average of 6.5 tons per acre. Higher ranking producers were allowed up to 6.19 AF/Ac, which translated to a water use efficiency factor of 8.0 acre inches per acre per ton of hay. This established that alfalfa yields could not surpass 9.3 tons per acre per year, which does not square with realities today.

The FMP also allocated water budgets to large turf facilities, including golf courses. Golf courses were required to confine their turf areas in size, and then allotted 6.0 AF/Yr/Ac for new facilities, and 4.8 AF/Yr./Ac for existing facilities. It was not until the Second Management Plan (SMP) (1990-2000) that a specific allotment for non-turf, low-water use areas (native plantings, typically providing from 40% to 60% of area with plant canopy coverage) at golf courses were allocated 1.5 AF/Yr. How this (Total Water Requirement ÷ Irrigation Efficiency) was developed was not disclosed. What Irrigation Efficiency is implied is equally obscure. However documents residing in the Roadside Development Section archives in 1997 revealed Water Budgets for Native Species ranging from 1 AF/Yr/Ac to 2 AF/Yr/Ac developed by Sacamono, Brady, and one other unknown.

Water Budgets on ADOT Freeways

Water budgeting on ADOT freeways requires that maintenance forces understand the design intent of the systems they operate. One of the most important features of ADOT Irrigation Plans has traditionally been a construction detail, which is typically titled Emitter Schedule.

EMITTER SCHEDULE

GPH	* Of Emit	Sym	Mult/Singl	Tube@Const.	Tube@Matur.	Out GPH	Run Hrs	Gals Const	Gals Mat	BotName
8.0	2	AS	M	8	8	1.0	5	40.0	40.0	Acacia smallii
8.0	2	*	M	8	8	1.0	5	40.0	40.0	Brahea armata
0.6	1		S	1	1	0.6	5	3.0	3.0	Carnegia gigantea
11.0	2	CF	M	11	11	1.0	5	55.0	55.0	Cercidium floridum
20.0	2	DS	M	10	10	2.0	5	100.0	100.0	Dalbergia sissoo
24.0	2	ES	M	12	2	2.0	5	120.0	120.0	Eucalyptus sideroxylon
14.0	2	PH	M	7	7	2.0	5	70.0	70.0	Pinus halepensis
10.0	2	PF	M	10	10	1.0	5	50.0	50.0	Pithecellobium flexicaule
20.0	2	PC	M	10	10	2.0	5	100.0	100.0	Prosopis chilensis
10.0	2	-	M	10	10	1.0	5	50.0	50.0	Sophora secundiflora

GPH	* Of Emit	Sym	Mult/Singl	Tube@Const.	Tube@Matur.	Out GPH	Run Hrs	Gals Const	Gals Mat	BotName
2.4	1		M	4	4	0.6	2	4.8	4.8	Baccharis 'Thompson'
0.6	1		S	1	1	0.6	2	1.2	1.2	Ambrosia deltoidea
0.6	1		S	1	1	0.6	2	1.2	1.2	Baileya multiradiata
8.0	2		M	8	8	1.0	2	16.0	16.0	Caesalpinia mexicana
8.0	2		M	8	8	1.0	2	16.0	16.0	Caesalpinia pulcherrima
3.0	1		M	2	2	0.6	2	2.4	2.4	Calliandra californica
0.6	1		S	1	1	0.6	2	1.2	1.2	Cereus peruvianus
3.0	1		M	5	5	0.6	2	6.0	6.0	Cordia parvifolic
3.0	1		M	3	3	1.0	2	6.0	6.0	Dasylirion wheeleri

Several forms were offered by the irrigation designers. The reason that the emitter quantity and flow rates would vary between species was because many different species could be irrigated by the same valve. The only way to irrigate plants ***somewhat*** according to their natural character and size was to provide more or less water per unit of time. The caveat there is intentional: Even plants of the same species and transplant size can mature into significantly differentsized individuals, and thus likely inclined to, if offered, significantly more water per year. But ADOT does not have the luxury, or mandate, to water same species, different canopy diameter, differently. Merely at construction, ADOT provides that one species PROJECTED to need 70 gals for the week could receive it, while a neighbor tree (different species) that needed 130 gals within the same time frame (irrigation set) could receive that amount. By design, Eldarica Pine receives more water per square foot of canopy than Palo Verde.

Some designers went further and specified plant size, and projected how many inches of water would be provided if the maintenance crew irrigated for the specified number of hours per year.

ComName	Extended Number of Emitters	No_Emit _Actual	# Emit's. calc'd.	Place-ment Style	Outlets_ Avail	Mult_Si ngle	Tubes_ Maturity	GPH_per _Outlet	Interval / Cycle (Days)	Run Hrs Each Cycle	Delivery Gals Each	Daily Appl'd. Inches	Quan. Plants	Mature Diam.	Canopy SF	Desired Ann. Inches	Design Ann. Inches	Desired Gals/ plnt/yr.	Design Gals/ plnt/ yr.	(to apply Peak In./Wk w/ 2 Da Constr't.)	Design GPH	Ann. Run Hrs.	Summary Gals / yr
SwAcacia	14.00	2.00	1.50	A	6.00	M	9.00	1.18	2.0	5.00	53.1	0.17	7	18.0	254.3	15.4	15.4	2,443	2,443	10.47	10.62	230	17,098
ShoestrAcacia	118.00	2.00	1.17	A	6.00	M	7.00	1.18	2.0	5.00	41.3	0.16	59	16.0	201.0	15.2	15.2	1,900	1,900	8.14	8.26	230	112,088
SissooTree	2.00	2.00	2.00	A	6.00	M	12.00	2.23	2.0	5.00	133.8	0.17	1	28.0	615.4	16.1	16.1	6,155	6,155	26.38	26.76	230	6,155
NativeMesquite	30.00	2.00	1.83	A	6.00	M	11.00	2.23	2.0	5.00	122.7	0.14	15	30.0	706.5	12.8	12.8	5,642	5,642	24.18	24.53	230	84,629
ChinesePistach	8.00	2.00	2.00	A	6.00	M	12.00	2.23	2.0	5.00	133.8	0.15	4	30.0	706.5	14.0	14.0	6,155	6,155	26.38	26.76	230	24,619
Tabebuia Impet	6.00	2.00	2.00	A	6.00	M	12.00	2.23	2.0	5.00	133.8	0.24	3	24.0	452.2	21.8	21.8	6,155	6,155	26.38	26.76	230	18,464
Green Desert Spoon	66.00	1.00	0.17	E	6.00	M	1.00	0.66	2.0	2.00	1.3	0.08	66	4.0	12.6	7.5	7.6	59	59	0.25	0.66	90	3,920
Red Hesperaloe	9.57	0.33	0.17	E	6.00	M	1.00	0.66	2.0	2.00	1.3	0.08	29	4.0	12.6	7.5	7.6	59	59	0.25	0.66	90	1,723
Green Cloud Sage	86.00	0.50	0.50	E	6.00	M	3.00	0.66	2.0	2.00	4.0	0.16	172	5.0	19.6	14.6	14.6	178	178	0.76	1.98	90	30,650
PurpTrlgLantana	45.00	1.00	0.67	E	6.00	M	4.00	0.66	2.0	2.00	5.3	0.22	45	5.0	19.6	19.5	19.4	238	238	1.02	2.64	90	10,692
Myoporum	15.00	1.00	1.00	B	6.00	M	6.00	1.18	2.0	2.00	14.2	0.23	15	8.0	50.2	20.4	20.4	637	637	2.73	7.08	90	9,558
PetiteOleander	166.00	1.00	0.50	E	6.00	M	3.00	0.66	2.0	2.00	4.0	0.16	166	5.0	19.6	14.6	14.6	178	178	0.76	1.98	90	29,581

Note in the second column from the right, the column labeled "Ann. Run Hrs." shows 230 hrs of irrigation for the trees, irrespective of the mature size or species. Yet, the annual prescriptive water budget ranges from 21.8 inches per year to 12.8 inches per year.

These are deemed to be net water requirements, meaning that irrigation efficiency and distribution uniformity are both set at 100%, or perfect. This is because irrigation efficiency is a multi-functioned parameter. There are several sources of efficiency, and from a truly technical stand-point, the factoring requires consideration of water distribution uniformity, which is not an irrigation efficiency term at all. The effect of water distribution uniformity upon the irrigation schedule is the same however, as the handling of application efficiency.

Generally, more water must be applied to compensate for operator misjudgment regarding when to start irrigation, and how long to run the system, which can only be estimated using weather data, or measured directly using plant and/or soil sensors. Distribution uniformity assumes that a proportion of the plants will always receive less water than the rest. This is because the system is not perfect in distributing the water, mostly due to hydraulics, equipment, and water quality effects. But we assume that the operator will apply extra water to most of the plants, just to irrigate the ones receiving the least amounts just right. This assumes he knows rather precisely when the soil around those few plants has reached some critical point of depletion, and then how long to irrigate to properly recharge those few root zones to full capacity.

Therefore a gross amount greater than the net amounts shown above is generally justified, and necessary.[1] More water must be applied to most of the plants, or the Owner suffers the consequences of a few stunted, possibly "health compromised" plants. Even very excellent irrigation systems possess micro-mechanical flaws, and this can aggravate other coincidentally occurring ecological and physiological disparities with plant individuals. Under-irrigation tends to be chronic, and accumulative. Same is true for over-irrigation. The primary solution is to improve water distribution uniformity. The secondary solution is improving timing. The third, most would agree, is shared between nutrition, soil salinity, and aeration.

[1] The water balance of an individual plant can be conducted, just like hydrologists attempt to account for all of the water within a hydrological sub-basin. Inputs minus outputs equals storage. Mining occurs in either situation when outputs exceed inputs. Naturally born plants are very good at adapting to good years and bad years, up to a point. But then they tend to possess normal tap roots. The effects of extended mining have decimated much of the forests of the Great Rocky Mountains. Stunted Pines along the freeways, suspected to be correlated with water pressure, are under avoidable attack.

United Sight-of-Way Assumes New Segments to Maintain

United Sight-of-Way is a very significant player in landscape maintenance in Central Arizona. They hold contracts for many miles of ADOT landscape maintenance….normally multi-year agreements. United Sight-of-Way staff is particularly well-versed in the operation of the central control systems, known commercially as the Motorola Irrinet. ADOT standardized on this particular platform way back in the '70's. Motorola was chosen because they had developed cutting-edge irrigation controllers for agriculture in Israel where drip irrigation flourished in the 1970's, featured radio telemetry of the data and control in duplex-mode, meaning that data and commands travelled in both directions, avoided telephone monthly expenses from the field to the central control office, and visa versa. ADOT meant to avoid monthly utility expenses.

Upon assuming the new 5-mile segment of freeway on North Phoenix along State Route 51, one of the requirements of such a hand-over from one contractor to the next, through competitive bidding and proof of capabilities, was to prepare an irrigation schedule. In the past, Ned, the Owner, had utilized a resource that worked in one of the municipal water conservation offices in the area. This individual was unable to provide the favor this time, so Water Balance received a call and a proposal to conduct the field work and analysis necessary to prepare schedules.

The task is complex for many reasons. But the bottom line is that the schedule needed to be straight-forward, and not burdensome to the company. The reason for the latter is because there were no specific requirements within the specification. There were no mandates for conservation potential, methodologies for validity or accuracy, or for first determining irrigation system performance characteristics, or how the 10 year-old system compared to the initial design. No need to see if each Palo Verde still possessed (10 each), properly operating, 2-gallon-per-hour emitters as provided for at construction in 1999.

What was known was that there were 5 controllers, and the irrigation systems appeared to be in obvious need of attention. Additionally, all but a few valves were irrigating just trees, while the rest were irrigating just shrubs. Water Balance just had to plunge forward anyway, dealing with all of the ambiguities as best they could. Though separate control of shrubs and trees has always been a design guideline, it can probably be shown that the root systems of the plants inhabiting Maricopa County urban freeways are virtually identical in depth and only different in horizontal scale; managers need to focus upon the upper 24” – 30” for shrubs and trees.

As they have reconciled the problem in the past, Water Balance technicians recognized that within each valve domain (plants irrigated by that valve), there was one specimen (individual) that was most average. This specimen had to be identified, and the species noted, as well as the canopy size, and relative canopy density. Furthermore, since typically 5 or 6 valves irrigate simultaneously, new valve groupings needed to be established, pairing similarities where possible. To add to the challenge in this regard, the wiring of the system limits the number of valves that can be actuated on a common wire leg.

In the interest of expediency, we continue with just a series of tables that were necessary to collect, group, consolidate, and match what the landscape needed, relative to what the original irrigation design set as flow rates in their Emitter Schedule.

But before we do this, we add that this was only a cursory exercise to satisfy a simplified requirement. United Sight-of-Way has the resources to install this program, and then begin the extensive repairs and corrections to the system to bring back up to the design standard.

Remaining work, not even proposed yet, prepares a new Emitter Schedule based on the current plant populations and characteristics. Then identify (in order to correct) other gross system maladies. Then, following these repairs and adjustments, a task ascertaining each of the system’s performance characteristics, knowing that each will likely be unique. Then prescribe adequate populations of soil moisture monitoring systems that can be used to adjust an ET-based **Base Irrigation Schedule.** This step addresses the other aspect facing irrigation managers: proper timing. Finally, training in how to fully utilize the flow sensors and flow accumulation feature in the software.

Controller

Paradise

Northbound- 1st quarter

Valve	S,T, S	Species	Radius	Canopy F	
6	S	Bird Paradise Yellow, Texas Sage, Cactus	4'	0.65	C
7	T	Palo Verde, Others	6.25'	0.7	A
8	S	Bird Paradise Red, Cactus, Other	2.50'	0.75	C

Northbound- 2nd quarter

Valve	S,T, S	Species	Radius	Canopy F	
9	T	Palo Verde, Other	12.50'	0.9	A
13	T	Palo Verde	10.5	0.8	A

Northbound- 3rd quarter

Valve	S,T, S	Species	Radius	Canopy F	
14	S	Bird Paradise, Texas Sage	3.25'	0.6	C
19	S	Lantana, Texas Sage	3'	0.7	B

Northbound- 4th quarter

Valve	S,T, S	Species	Radius	Canopy F	
20	T	Palo Verde, Mesquite	13'	1	C
23	S	Others	3'	0.8	B
24	T	Mesquite, Others	16'	0.75	C

Southbound- 1st quarter

Valve	S,T, S	Species	Radius	Canopy F	
22	T	Palo Verde, Mesquite	14.5'	1	C
21	S	Texas Sage, Lantana	3'	0.8	B

Southbound- 2nd quarter

Valve	S,T, S	Species	Radius	Canopy F	
18	S	Texas Sage	3 1/2'	0.75	B
17	T	Mesquite, Palo Verde	11 1/2'	0.7	A
12	S	Other	4'	0.65	B

Southbound- 3rd quarter

Valve	S,T, S	Species	Radius	Canopy F	
11	T	Palo Verde, Mesquite	11'	0.9	A
2	S	Bird Paradise, Texas Sage	3.25'	0.75	B

Southbound- 4th quarter

Valve	S, T, S	Species	Radius	Canopy F	
3	T	Palo Verde, Others	15.50'	0.7	A
4	T	Palo Verde, Others	7.40'	0.75	A
5	S	Cactus, Texas Sage	3'	0.8	A

	A	B	C
TREEF	0.78		0.92
SHRUBF	0.80	0.74	0.67

				AGE RADIUS	AVG DIAM
S	5	3	A	3	6
S	19	3	B		
S	21	3	B	3.292	6.58
S	2	3.25	B		
S	23	3	B		
S	18	3.5	B		
S	12	4	B		
S	6	4	C		
S	8	2.5	C	3.25	6.5
S	14	3.25	C		
T	7	6.25	A		
T	11	11	A		
T	9	12.5	A		
T	13	10.5	A	10.68	21.4
T	17	11.5	A		
T	3	15.5	A		
T	4	7.5	A		
T	22	14.5	C		
T	20	13	C	14.5	29
T	24	16	C		

	A	B	C
TREEF	0.88		0.92
SHRUBF	0.80	0.74	0.67

Data Table Using Data Provided by Sight-of-Way Irrigation Technicians Following Training by Water Balance

PARADISE Trees – Schedule A						
					Leaf Area Factor *	0.78
					Simple Canopy Area (Sq.Ft.)	363
					Canopy Diameter (Ft)	21.5
					Species Factored "Area Irrigated" *	221
Drought Tolerance Category			avg. inches	AVG. INCHES		
2			12	12		1,650
					Hours of Irrigation / Yr.	146
Drought Tolerance Category			avg. inches	AVG. INCHES	emit #	emit Q	INCHES APPLIED (NET)
2			12	12	10	1.18	12.53

+ + SHRUBS Before Consideration of Rainfall, Not Accounting for Irrigation Efficiency Irrigation Scheduling[1] – cycles per

	Interval (Days Bet'wn. Irriga'n.)	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	total
	2													
	3.5					9	9	9	9	9				
	4													
	7													
	14			2	2						2			
	30	0	1									0	0	
Hrs Irrig/mo.		0	1	2	4.0	27.0	27.0	27.0	27.0	27	4	0	0	146
Run Time ea. Cycle (hrs)		0.0	1.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	2.0	0.0	0.0	

Schedule Table for Type A Schedule (12" per Year) for the Paradise Lane Controller Using Data Table Data

Site Name ___PARADISE CONTROLLER______________________

Hours per Month

Valve Group(s)	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	TOTAL
7,11,9,13	0.0	1.0	2.0	4.0	27.0	27.0	27.0	27.0	27.0	4.0	0.0	0.0	146
17,3,4	0.0	1.0	2.0	4.0	27.0	27.0	27.0	27.0	27.0	4.0	0.0	0.0	146
22.20.24	0.0	3.0	6.0	6.0	43.2	43.2	43.2	43.2	43.2	8.0	0.0	0.0	239
5	0.0	0.0	1.6	1.6	1.6	10.4	10.4	10.4	1.6	1.6	0.0	0.0	39
19,21,2,23,18,12	0.0	0.0	0.8	0.8	10.4	10.4	10.4	10.4	1.6	1.6	0.0	0.0	46
6,8,14	0.0	0.8	0.8	1.6	10.4	10.4	10.4	10.4	1.6	1.6	0.0	0.0	48

Summary Table of Type A Schedule (12" per Year) for the Paradise Lane Controller Using Schedule Type A Results – Valve Grouping Established

WATER BUDGET														
(NET ANNUAL INCHES)														
	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec		
12	0	2.354102	2.998323	5.494343	18.22739	18.22739	18.22739	18.22739	16.25057	2.633425	0.959661	0	103.6	**103.6**
15	0	2.013779	2.93738	4.027558	9.062006	10.30887	10.30887	10.30887	9.062006	2.013779	1.00689	0	61.05	**61.05**
18	0	3.0912	6.779796	7.056399	20.25813	20.25813	21.95335	21.95335	20.25813	3.34263	1.248888	0	126.2	**126.2**
12	0	0	1.56085	1.56085	5.420017	10.14553	10.14553	10.14553	1.56085	1.56085	0	0	42.1	**42.1**
15	0	1.462244	1.854997	1.854997	15.51153	16.42553	16.42553	15.51153	2.107135	1.966519	0	0	73.12	**73.12**
18	0	2.198149	2.198149	4.396297	16.00737	16.00737	16.00737	16.00737	4.396297	2.138766	0	0	79.35714	**79.35714**
a	0	0.028777	0.028777	0.057554	0.168345	0.168345	0.168345	0.168345	0.168345	0.028777	0.014388	0		
	0	0.025478	0.025478	0.050955	0.171975	0.171975	0.171975	0.171975	0.171975	0.025478	0.012739	0		
	0	0.024242	0.048485	0.072727	0.163636	0.163636	0.163636	0.163636	0.163636	0.024242	0.012121	0		
	0	0.006849	0.013699	0.027397	0.184932	0.184932	0.184932	0.184932	0.184932	0.027397	0	0		
	0	0.028269	0.028269	0.056537	0.190813	0.190813	0.190813	0.190813	0.095406	0.021201	0.007067	0		
The proportions of annual hours of irrigation														
b	0	0.030257	0.060514	0.060514	0.136157	0.177005	0.177005	0.177005	0.136157	0.030257	0.015129	0		
	0	0.035714	0.035714	0.071429	0.160714	0.160714	0.160714	0.160714	0.160714	0.035714	0.017857	0		
c	0	0.034483	0.068966	0.068966	0.155172	0.155172	0.155172	0.155172	0.155172	0.034483	0.017241	0		
	0	0.021918	0.043836	0.054795	0.172603	0.172603	0.172603	0.172603	0.172603	0.010959	0.005479	0		
	0	0.023669	0.071006	0.071006	0.159763	0.159763	0.159763	0.159763	0.159763	0.023669	0.011834	0		
	0	0.012552	0.025105	0.025105	0.180753	0.180753	0.180753	0.180753	0.180753	0.033473	0	0		
	0	0.029851	0.059701	0.059701	0.134328	0.134328	0.201493	0.201493	0.134328	0.029851	0.014925	0		
a	0	0	0.040816	0.040816	0.040816	0.265306	0.265306	0.265306	0.040816	0.040816	0	0		
	0	0	0.033333	0.033333	0.216667	0.216667	0.216667	0.216667	0.033333	0.033333	0	0		

Super-Summary Table of All Schedule Types (e.g. 12", 15" & 18" per Year) for the Paradise Lane Controller Using Schedule Type A Results – Valve Grouping Intact But Not Reported

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	
TREES AVERAGE HOURS	-	2.5	4.2	5.5	15.8	16.3	16.8	16.8	15.2	2.7	1.1	-	97.0
SHRUBS AVERAGE HOURS	-	1.2	1.9	2.6	12.3	14.2	14.2	13.9	2.7	1.9	-	-	64.9
											1.0		
fudge factor	1.15												

WATER PLAN - SHEA BLVD. TO BELL RD. - CONDENSED VERSION	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	ANNUAL HOURS OF IRRIGATION
TREES AVERAGE HOURS PER MONTH	-	2.9	4.9	6.4	18.2	18.7	19.4	19.4	17.5	3.1	1.2	-	111
SHRUBS AVERAGE HOURS PER MONTH	-	1.4	2.2	3.0	14.2	16.3	16.3	16.0	3.1	2.2	-	-	75

Gallons per Month at Design Flow Rates (Most Typical Trees)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	Gallons per Year
Acacia smallii	-	23	39	51	146	150	155	155	140	25	10	-	892
Brahea armata	-	23	39	51	146	150	155	155	140	25	10	-	892
Cercidium floridum	-	31	54	70	200	206	213	213	192	34	14	-	1226
Pinus halepensis	-	40	68	89	255	262	271	271	245	43	17	-	1561
Prosopis chilensis	-	57	97	127	365	374	387	387	349	61	25	-	2230
Sophora secundiflora	-	29	49	64	182	187	194	194	175	31	12	-	1115

Gallons per Month at Design Flow Rates (Most Typical Shrubs)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	Gallons per Year
Baccharis 'Thompson'	-	3	5	7	34	39	39	38	7	5	-	-	179
Caesalpinia mexicana	-	11	17	24	113	131	131	128	25	17	-	-	597
Calliandra californica	-	2	3	4	17	20	20	19	4	3	-	-	90
Cordia parvifolia	-	4	6	9	42	49	49	48	9	7	-	-	224
Dodonaea viscosa	-	4	6	9	42	49	49	48	9	7	-	-	224
Hesperaloe parviflora	-	1	2	3	14	16	16	16	3	2	-	-	75
Leucophyllum frutescens	-	6	9	12	57	65	65	64	12	9	-	-	298

Ultimate Schedule for Submittal– Valve Grouping Masked for Clarity

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Problems and Questions / Opportunities

- If municipalities could argue that landscapes were not being maintained in the quality and plant densities depicted in the Construction Plans and Specifications, would they be in a position to require ADOT to start paying for the water they use? What is the value of the plants on a typical mile?
- Are the plants the only way to prevent erosion of the slopes?
- If freeway landscapes were applying perfect species-specific proportions of water to 90% of the square footage of total canopy area per mile, what would be the irrigation efficiency, and irrigation manager performance of those operating those systems?

- Should the universities conduct water balance studies to establish crop coefficients[2] for native species grown on freeways, or should they use tax-payer dollars to establish robust field protocols, data analysis tools, and ultimately irrigation scheduling models using direct measurement of soil moisture, for the masses? What happens when Mesquite is like Alfalfa?
- Are 3 or 4 well placed $200 soil moisture sensors always better than a well-placed and maintained $4,000 weather station? Is this more or less true when plant is grass, versus woody plant, like Cotton or Bougainvillea?
- Looking at the Schedule Table, is Water Balance justified in setting the "bar" rather low, at 12" per square foot of canopy area per year (net), and then discounting this further with another discounting factor for leaf area of the average specimen (which "just so happened" to be most typical)?

A Typical ADOT Mile			
		GALLONS	**ACRE FT.**
ANNUAL WATER REQUIRMENT (AWR) (GALS) BASED ON PLANT PALETTE BELOW		2,757,900	8
REFURBISHED SYSTEM, GROSS ANNUAL WATER REQUIREMENT @ DU = 88% AND APP. EFF. = 85%		3,687,032	11
UNREFURBISHED SYSTEM GROSS ANNUAL WATER REQUIREMENT @ DU = 60% AND APP.EFF = 85%		5,407,647	17
PROJECTED DIFFERENCE (GALS.) PER YEAR		1,720,615	
	Acre Feet	Potable Value	Annual COST for Slippage
PROJECTED DIFFERENCE (AC. FT.) PER YEAR	5.28	$ 490.00	$ 2,587.41

	PLANTS PRESENT -TYPICALLY		
	Species	**Gals/Yr**	**Quantity**
Tree	EUC	3000	150
Tree	PC	5500	225
Tree	AM	1500	150
Tree	VA	2100	150
Shrub	Bg	240	500
Shrub	Rbk	108	500
Shrub	Lt	162	500
Shrub	Lc	162	500
Shrub	Ef	54	500
Shrub	Cp	324	300
Shrub	Cac	54	300
Shrub	Lm	180	300
	Net Annual Water Reqm't. at Maturity	**2,757,900**	

[2] Crop coefficients simply provide the species-specific relationship between the species studied and a reference species. Typical reference plants are alfalfa and grass, as in turf. Reference plants are monitored using soil moisture sensors or other gravimetric techniques to measure consumptive use and evaporation and account for deep percolation, under perfect growing conditions and maximum yield i.e. full irrigation.