WADI HANIFAH:
COMPREHENSIVE DEVELOPMENT PLAN

Methods Document

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This Methods Document accompanies a *Landscape Performance Series* Case Study Brief. It was produced through the 2015 Landscape Architecture Foundation's *Case Study Investigation* (CSI) program, a unique research collaboration that matches LAF-funded faculty-student research teams with leading practitioners to document the benefits of exemplary high-performing landscape projects.

The full case study can be found at:
https://landscapeperformance.org/case-study-briefs/wadi-hanifah

Landscape Performance Benefits

Environmental benefits

- **Removed 17.7 million cu ft of industrial and municipal waste, enough to fill a football stadium, from an area of 4 sq miles.**

Methodology

Quantities were taken from *Moriyama & Teshima Planners Inc, Wadi Hanifah Restoration Project. Report. March 2010, page 11*. The area was confirmed using contract boundaries in original CAD drawings and further validated via Google Earth air photos.

Limitations

No construction logs were available to validate actual waste removal quantities. No soil samples were available to confirm soil quality.

- **Increases riparian habitat by creating 114.9 acres of indigenous plant species, plus an additional 35 acres of seeded native grasses and perennials.**

To establish the actual project contribution to new riparian habitat we calculated the total area of the 42-mile riverbed corridor that was re-vegetated with native plant species. Our calculations indicate that the renaturalized area includes 1,805 planting cells in 35 distinct configurations[1] including a total of:

- 28,021 trees (7 different species or varieties)
- 40,166 shrubs (20 different species or varieties)
- 44,719 grasses (8 different species or varieties)
- 33.54 acres of seeded grasses
- 1.38 acres of seeded perennials.

Interestingly, the total planting cell and seeded areas account for only 4% of the total project area, which may reflect the fact that the project boundaries include all the land (such as parks) or infrastructure (such as roadways) within the publicly-owned river corridor.

Methodology

Considering the fact that the entire 42-mile river corridor was previously disturbed and littered with industrial and municipal waste, for the purposes of this case study we assumed that the renaturalized area can be defined as the re-vegetated area within the project boundary. While not a perfect definition, this distinguishes the new areas with high river habitat value from those composed almost exclusively of re-profiled mineral soils.

[1] Reports from the designer state that 54 cell configurations were used. The discrepancy may reflect subsequent work conducted in zones 1 and 5, which were not considered within the present case study.

The renaturalization scheme proposed by Moriyama & Teshima Planners (MTP) is composed of 35 different types of planting cells ranging from 1,076 sf (100 square meters) to 6,548 sf (600 square meters) in size. Each planting cell contains a specific mixture of indigenous trees, shrubs, perennials, and grasses that once thrived in the wadi drainage basin. Each cell's mix of plant species is adapted to a specific set of riverbed micro-conditions to account for variations in soil and humidity. **Figure 2** shows the typical composition and layout of a plant cell.

Given its size, the Wadi Hanifah project was broken down into 5 zones, 3 of which were identified for significant renaturalization initiatives (these 3 zones are further divided into 6 sub-zones, see **Figure 1**). Construction CAD drawings and the planting schedule obtained from MTP allowed the calculation of the overall site area for each zone, the number and size of plant cells within each zone, and the percentage of each zone that is occupied by plant cells (See **Appendix 1**). The plant schedule (see **Appendix 2**) was also used to establish total quantities by zone.

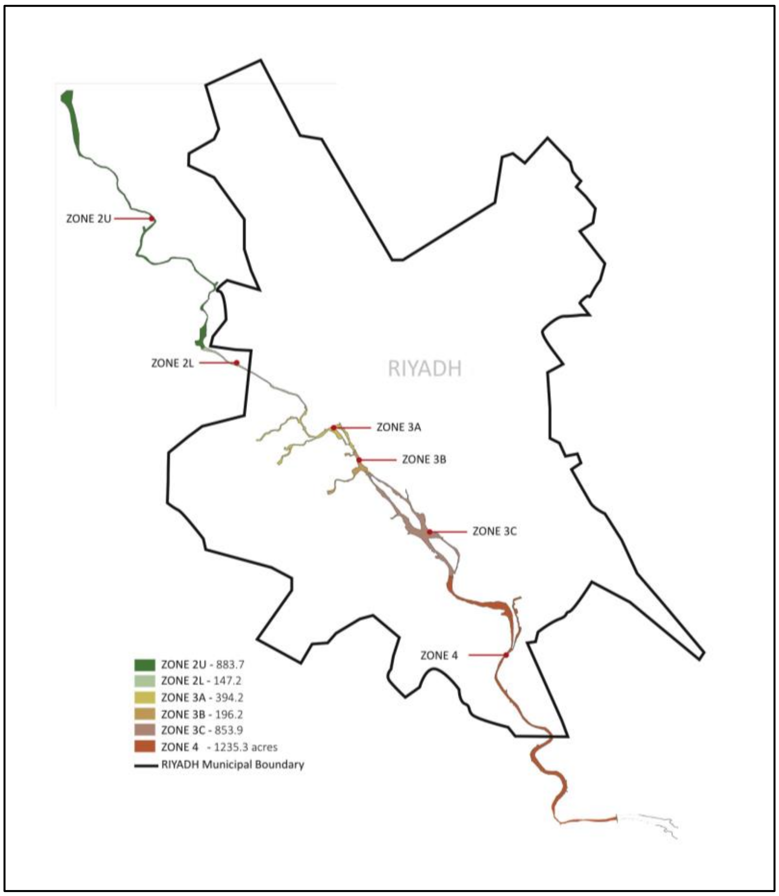

Figure 1. Extent of river corridor renaturalization with respective sub-zones.

<u>CALCULATIONS SUMMARY</u>

Wadi Hanifah Zone 2

Overall zone area = 1,030.5 acres
Planting cells total area = 26.2 acres
Percentage vegetated area = 2.5%

Wadi Hanifah Zone 3

Overall zone area = 1,443.6 acres

Plantation cells total area = 61.3 acres
Percentage vegetated area = 4.2%

Wadi Hanifah Zone 4
Overall zone area = 1,234.8 acres
Plantation cells total area = 27.3 acres
Percentage vegetated area = 2.2%

Wadi Hanifah Total Renaturalized Area
Overall project area = 3,708.9 acres
Plantation cells total area = 114.9 acres
Seeded area = 34.9 acres
Total new vegetated area = 149.8 acres
Percentage vegetated area = 4.0%

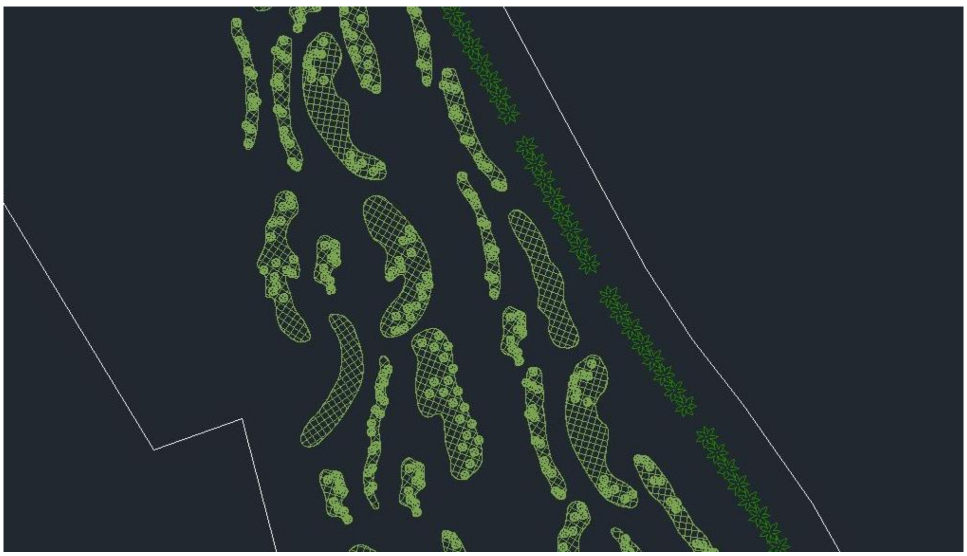

Figure 2. Typical plant cell layout and distribution (source: MTP)

Limitations

This method relies on the premise that the project's renaturalized area is equal to its re-vegetated area, which does not recognize the complex web of conditions in desert habitats nor accounts for the dispersion potential of the introduced vegetated areas beyond the first year of implementation (see next benefit below). Furthermore, since the method relies on construction drawings it may be compromised by discrepancies between these drawings and as-built conditions. The method would also be affected by the actual survival rate of introduced plant specimens.

To address these last 2 concerns, a sample of the construction drawings was compared to recent aerial photos of the site via Google Earth. On this basis, it appears that designed and actual cell coverage for the entire project are similar. Ground-truthing would prove more precise and could also help establish which initial planting cell types thrived and which (if any) died out, and at what rate.

- **Through self-propagation in these areas expanded by an additional 47 acres between 2010 and 2015.**

The plant cells were intended to serve as seed propagators to colonize the non-vegetated areas within the project boundary and beyond. While the project was only completed in 2010, we thought it would be interesting to attempt an assessment of the growth in vegetated coverage since.

Methodology

We used historical satellite imagery embedded in Google Earth to compare the size of the original plant cells with the 2015 vegetation coverage. 18 aerial photos periods are available, covering almost every year between 2001 and 2015. Interestingly, this allows for a comprehensive tracking of the evolution of the project and a simple means of comparison between before and after project site conditions. 2015 aerial photos were used to draw the outlines of vegetated areas, which were then overlaid on the original CAD construction drawings.

Given the size of the project area, sub-zone 3A-3 was selected as a sample area for the calculations. This sub-zone is relatively central to the project area and includes 18 cells, one for each of the cell types most commonly found throughout the project. The measured increase in cell area between June 29, 2010 and January 1, 2015 varies between 10.0% and 91.2%. The average growth for the entire sub-zone is 40.8%. Interestingly, a comparison of the 2010 aerial photo with the design plans indicates a 5.9% growth, which either reflects the growth that occurred between the construction itself and the date the air photo was taken or the fact that the cells were not exactly built as per the plans.

Extrapolating from the sub-area's 40.8% propagation rate we estimate the total project increase in cell area since 2010 to be 46.9 acres.

Figure 3. Example of plant cell growth comparison between design documents and 2015 air photo (Sources: plan, MTP; air photo, Google Earth and DigitalGlobe 2015)

Figure 4. Cell growth in sub-area 3A-3 between 2010 (in green, top left) and 2015 (in red, top right). (Sources: plan, MTP, air photo; Google Earth and DigitalGlobe 2010-2015)

CELLS TYPE	CELL TYPE AREA (sq. m.)	SAMPLE	AREA 2010	AREA 2015	DIFFERENCE	GROWTH (%)
302a/L-903	337.4	1	378.1	532.4	154.3	40.81%
302b/L-903	300.3	1	301.1	482.1	181.0	60.11%
303a/L-904	464.4	1	538.8	694.2	155.4	28.84%
303b/L-904	98	1	130.8	250.1	119.3	91.21%
304a/L-905	300	1	346.1	455.2	109.1	31.52%
304b/L-905	281.9	1	286.7	340.2	53.5	18.66%
305a/L-906	506.7	1	516.3	762.3	246.0	47.65%
305b/L-906	358.3	1	363.3	479.7	116.4	32.04%
306a/L-907	511.7	1	513.2	701.5	188.3	36.69%
306b/L-907	518.5	1	520.1	724.9	204.8	39.38%
307a/L-908	302.7	1	340.3	501.4	161.1	47.34%
307b/L-908	270	1	276.3	325.9	49.6	17.95%
307c/L-908	194.3	1	207.4	341.5	134.1	64.66%
308a/L-909	165.4	1	172.7	189.6	16.9	9.79%
308b/L-909	222.6	1	224.5	269.3	44.8	19.96%
308c/L-909	132.5	1	134.3	224.5	90.2	67.16%
309a/L-910	145.7	1	152.2	269.3	117.1	76.94%
309b/L-910	126.9	1	143.8	265.9	122.1	84.91%
Total:	**5237.3**		**5546.0**	**7810.0**	**2264.0**	
Difference between design cells and 2010 actual:			**308.7**	**5.9%**		
Growth between 2010 and 2015:			**2264.0**	**40.8%**		

Note: All areas in square metres

Figure 5. Cell growth calculation sheet for sub-zone 3A-3 (2010-2015)

Limitations

The resolution of the air photos makes it difficult to distinguish clearly the edges of the plant cells or to distinguish plant cells from adjacent humid areas that show as a darker color. The dimensional distortion inherent in overlaying air photos with CAD construction drawings also required an imperfect scaling operation, which further reduces the reliability of the plant cell edge configuration. This was not an issue when comparing Google Earth air photos from different periods. Finally, the limited number of air photos available required us to compare cell conditions at different periods of the year (June 2010 and January 2015), which would presumably affect plant condition and, as a result, the clarity of cell edges.

Due to the size of the site and time constraints, we used a representative sample area to extrapolate propagation growth for the entire wadi bed. This does not account for the possibility of significant dispersion variations in certain areas of the riverbed. Again, ground-truthing would be required to establish the precision of the calculated plant cell growth rate.

- **Supports 15 bird species, 9 fish species, 3 mollusk species, 2 amphibian species, and 3 reptile species as observed on site.**

Birds

Bittern, egret, mallard duck, heron, long-beaked bird sp. (unidentified), moorhen, black-winged stilt, woodpecker, eagle, seagull, mynah, house sparrow, spotted dove, pigeon, kingfisher

Fish

Tilapia, African jewelfish (cichlid), molly (sailfin and black-spotted), gambusia (mosquito fish), African and sucker mouth catfish, koi carp

Mollusks

Melanoide snail, ram horn snail, Asian clam

Amphibians

Frog sp., turtle sp.

Reptiles

Common house gecko, Arabian spiny-tailed lizard, water snake

Insects

Grasshopper, dragonfly, honey bee

Figure 6. Fauna inventory. Nelson Environmental Inc. 2013. *Fauna of Wadi Hanifah. Photo Compilation of Fauna Diversity in Wadi (1st Edition). May 2009 – September 2013.* Report.

Methodology

Figures were taken from Nelson Environmental Inc. 2013. *Fauna of Wadi Hanifah. Photo Compilation of Fauna Diversity in Wadi (1st Edition). May 2009 – September 2013.* Report.

Limitations

The evidence remains anecdotal and limited to photographic records from the consultant and ADA personnel. No mammals were included in the inventory. Furthermore, many species observed are non-native and / or considered invasive (i.e. the house sparrow, the koi carp) and as such cannot serve as indicators of a healthy ecosystem.

- **Sequesters 89,144.9 lbs of atmospheric carbon annually in 28,021 newly-planted trees.**

Methodology

The method used for calculating carbon sequestration for trees planted in the Wadi Hanifah project was based on the U.S. Department of Energy's 1998 *Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings.* This method calculates carbon sequestration by multiplying specific coefficients associated with the number of trees planted, tree age, tree survival rate, planted tree size (bound and burlap or containers), and the annual sequestration rate of tree species of a certain age (see **Figure 7**). Using a timeframe of 6 years from the original planting date (2008), we determined carbon sequestration figures associated with the urban forest of the project (e.g. the trees planted within the zones identified in **Figure 1**).

RBAN FORESTRY CARBON SEQUESTRATION WORKSHEET

Species name	Tree Type (H or C)	Growth Rate	Tree Age	Number of Trees Planted	Surv
	Hardwood or Conifer	Slow , Moderate, Fast	2014	from MTP plant list	refe
acia gerrardii	H	M	6	3,884	
acia nilotica	H	M	6	4,460	
acia tortilis	H	S	6	11,521	
hoenix dactylifera	H	S	6	4,634	
marix aphylla	H	M	6	420	
marix nilotica	H	M	6	1,774	
zyphus spina-christi	H	S	6	1,328	

Total
Total
Equiv

Figure 7. Carbon sequestration modeling assumptions.

Limitations of Methodology

The international arid desert location of the project made the use of American online calculators such as i-Tree or the National Tree Benefit Calculator impractical. Calculation coefficients relevant to Saudi Arabia could not be obtained so survival rate and annual sequestration coefficients of Saudi tree species were established using comparative American species (in terms of physical characteristics and growth pattern), using the USDE database. Growth rates for each individual species were obtained from the following sources:

Acacia gerrardii Reference

Arid Zone Trees. 2015. *Acacia gerrardii Grey-haired Acacia*. [PDF]
http//w ww.aridzonetrees.com/AZT%20Interactive%20Buttons/Tree%20Index/Acacia.htm
Accessed August 6, 2015

Acacia nilotica Reference

Food and Agriculture Organization of the United Nations. Le Houerou.2015. *Acacia nilotica.* [PDF]
http//w ww.fao.org/ag/AGP/AGPC/doc/Gbase/data/Pf000124.HTM
Accessed August 6, 2015

Acacia tortils Reference

Arid Zone Trees. *Acacia tortils Umbrella Thorn*. [PDF]
http//w ww.aridzonetrees.com/AZT%20Interactive%20Buttons/Tree%20Index/Acacia.htm
Accessed August 6, 2015

Phoenix dactylifera Reference

University of Arizona, and Arizona Board of Regents. . *Phoenix dactylifera Date Palm*
https://ag.arizona.edu/pima/gardening/aridplants/Phoenix_dactylifera.html
Accessed August 6, 2015

Tamarix aphylla Reference

Plants for the Future. 1982. *Tamarix aphylla Athel Tamarisk PFAF Plant Database*. [PDF]
http//w ww.pfaf.org/user/Plant.aspx?LatinName=Tamarix+aphylla
Accessed August 6, 2015

Tamarix nilotica Reference

Goldsmith, F.B. and N. Smart. 1982. *Age, spacing and growth rate of Tamarix as an indication of lake boundary flutuation at Sebkhet Kelbia, Tunisia.*
J. Arid Environ. 5: 43-51

ZizRphus spina-christi eference

World Agroforestry Cenre. *Ziziphus spina-christi*
http//w ww.worldagroforestry.org/treedb/AFTPDFS/Zizyphus_spina-christi.[PDF]
Accessed August 6, 2015

As we were unable to access accurate local air pollution levels, we were also unable to delve into a more elaborate methodology for a more precise carbon sequestration figure for the planted trees in the project. Also, this method does not account for the carbon sequestration achieved by other plant species.

Tree Age (yrs)	Survival Factors by Growth Rate			Annual Sequestration Rates by Tree Type and Growth Rate (lbs. carbon/tree/year)					
				Hardwood			Conifer		
	Slow	Moderate	Fast	Slow	Moderate	Fast	Slow	Moderate	Fast
0	0.873	0.873	0.873	1.3	1.9	2.7	0.7	1.0	1.4
1	0.798	0.798	0.798	1.6	2.7	4.0	0.9	1.5	2.2
2	0.736	0.736	0.736	2.0	3.5	5.4	1.1	2.0	3.1
3	0.706	0.706	0.706	2.4	4.3	6.9	1.4	2.5	4.1
4	0.678	0.678	0.678	2.8	5.2	8.5	1.6	3.1	5.2
5	0.658	0.658	0.658	3.2	6.1	10.1	1.9	3.7	6.4
6	0.639	0.639	0.644	3.7	7.1	11.8	2.2	4.4	7.6
7	0.621	0.621	0.630	4.1	8.1	13.6	2.5	5.1	8.9
8	0.603	0.603	0.616	4.6	9.1	15.5	2.8	5.8	10.2
9	0.585	0.589	0.602	5.0	10.2	17.4	3.1	6.6	11.7

Figure 8. Example of survival factors and annual carbon sequestration rates for common urban trees used to extrapolate values for Saudi species. Source: U.S Department of Energy's 1998 *Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings. Page*

- **Reduces potable water consumption by 92.5 million gallons per day with the use of bioremediated urban wastewater for park amenities and irrigation.**

Source: Volumes taken from Moriyama & Teshima Planners Inc. 2010. *Wadi Hanifah Restoration Project*. March 2010, page 11. See the LAF Wadi Hanifah Bioremediation Facility case study for details.

Social benefits

- **Attracts 200,000 visitors per week, re-establishing the social, cultural, and recreational significance of the wadi for Riyadh residents.**

Methodology

Number of visitors comes from the Arriyadh Development Authority. The Wadi Hanifah has been voted number 11 of 37 things to do in Riyadh by Trip Advisor reviewers - ahead of all other public open spaces in Riyadh. Of 86 reviewers, 62 rated the river park corridor as "very good" or "excellent".

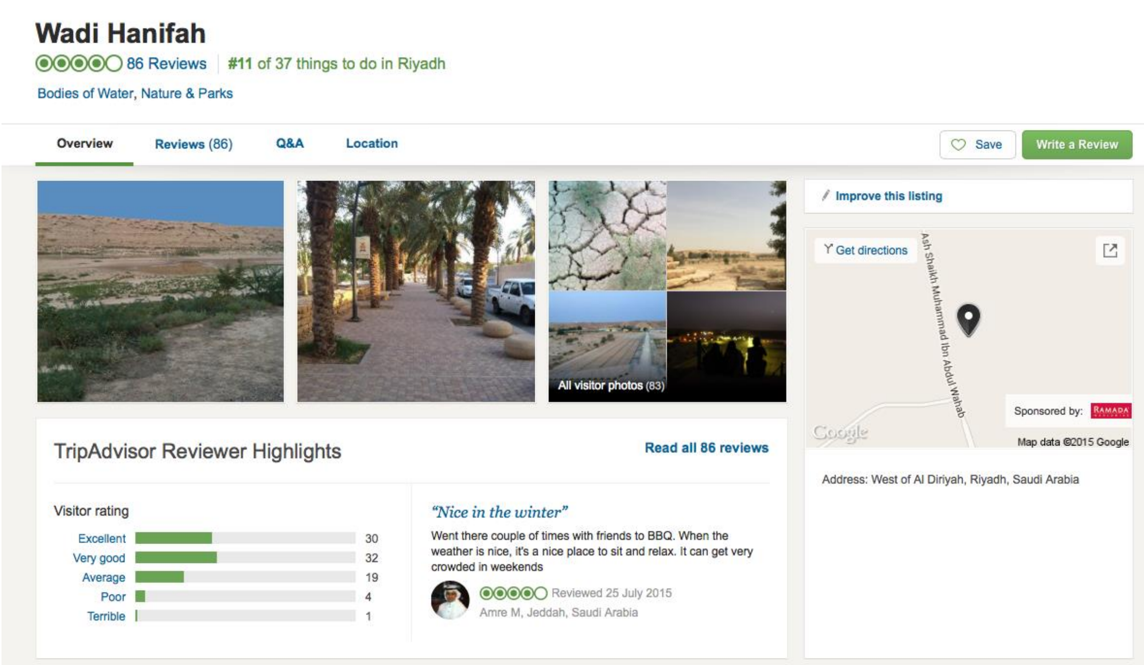

Figure 9. Trip Advisor ranking of Wadi Hanifah as a visitor destination. Source: http://www.tripadvisor.ca/Attraction_Review-g293995-d2646179-Reviews-Wadi_Hanifah-Riyadh_Riyadh_Province.html. Retrieved August 6, 2015.

Search functions embedded in 3 social media platforms – Facebook, Instagram, and Twitter – were used to track the number of posts for variations of Wadi Hanifah between 2009 and 2015.

SOCIAL MEDIA ANALYSIS		2009	2010	2011	2012	2013	2014	2015
FACEBOOK								
"WADI HANIFAH"		N/A	4	3	21	30	13	15
INSTAGRAM								
#wadihanifah	184 total posts	N/A	posts from 2010-2012		113	16	33	22
#wadihanifa	448 total posts	N/A	posts from 2010-2012		260	35	64	89
"Wadi Hanifah Riyadh		N/A	N/A	N/A	N/A	N/A	17	135
TWITTER								
"WADI HANIFAH"		2	8	25	62	24	25	14

Figure 30. Mentions of Wadi Hanifah in selected social media platforms

Limitations (draft)

The numbers of posts generated are impossibly low, especially given that a Google search of "Wadi Hanifah" returns 146,000 hits, "Wadi Hanifah blog" 28,800 hits, and "Wadi Hanifah picture" 69,700 hits. This may reflect filtering and management restrictions within each of the social media platform.

Works Cited

Moriyama & Teshima Planners Inc. 2010. *Wadi Hanifah Restoration Project*. March.

Nelson Environmental Inc. 2010. *Bioremediation and Surface Water Monitoring Report.* February.

U.S Department of Energy's. 1998. *Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings.*

Cell Type / Drawing reference	Cell Area (sq. metres)	Zone 2u		Zone 2l		Zone 3a		Zone 3b		Zone 3c		Zone 4	
		Quantity	Area (sq. m.)	Quantity	Area (sq. m.)	Quantity	Area (sq. m.)	Quantity	Area (sq. m.)	Quantity	Area (sq. m.)	Quantity	Area (sq. m.)
300/L-901													
301/L-902													
302a/L-903	337.4		0.0	7	2361.8	39	13158.6	5	1687.0	50	16870.0	44	14845.6
302b/L-903	300.3		0.0	2	600.6	8	2402.4	5	1501.5	11	3303.3	9	2702.7
303a/L-904	464.4		0.0	2	928.8	18	8359.2	12	5572.8	17	7894.8	7	3250.8
303b/L-904	98		0.0	28	2744.0	81	7938.0	18	1764.0	58	5684.0	49	4802.0
304a/L-905	300		0.0	6	1800.0	20	6000.0	4	1200.0	18	5400.0	18	5400.0
304b/L-905	281.9		0.0	9	2537.1	8	2255.2	6	1691.4	18	5074.2	12	3382.8
305a/L-906	506.7		0.0	0	0.0	8	4053.6	7	3546.9	12	6080.4	19	9627.3
305b/L-906	358.3		0.0	6	2149.8	41	14690.3	6	2149.8	37	13257.1	36	12898.8
306a/L-907	511.7		0.0	3	1535.1	4	2046.8	6	3070.2	22	11257.4	21	10745.7
306b/L-907	518.5		0.0	3	1555.5	10	5185.0	8	4148.0	27	13999.5	15	7777.5
307a/L-908	302.7		0.0	2	605.4	8	2421.6	8	2421.6	57	17253.9	54	16345.8
307b/L-908	270		0.0	13	3510.0	4	1080.0	5	1350.0	11	2970.0	11	2970.0
307c/L-908	194.3		0.0	28	5440.4	45	8743.5	9	1748.7	31	6023.3	35	6800.5
308a/L-909	165.4		0.0	4	661.6	16	2646.4	2	330.8	1	165.4	7	1157.8
308b/L-909	222.6		0.0	21	4674.6	14	3116.4	2	445.2	5	1113.0	10	2226.0
308c/L-909	132.5		0.0	33	4372.5	40	5300.0	5	662.5	33	4372.5	29	3842.5
309a/L-910	145.7		0.0	30	4371.0	8	1165.6	4	582.8	5	728.5	11	1602.7
309b/L-910	126.9		0.0	15	1903.5	16	2030.4	2	253.8	1	126.9	2	253.8
310/L-911	535.5	2	1071.0		0.0		0.0		0.0		0.0		0.0
311/L-912	1036.6	2	2073.2		0.0		0.0		0.0		0.0		0.0
312/L-913	378.4	13	4919.2		0.0		0.0		0.0		0.0		0.0
313/L-914	298.1	9	2682.9		0.0		0.0		0.0		0.0		0.0
314/L-914	283.4	5	1417.0		0.0		0.0		0.0		0.0		0.0
315/L-915	507.1	8	4056.8		0.0		0.0		0.0		0.0		0.0
316/L-915	359.9	8	2879.2		0.0		0.0		0.0		0.0		0.0
317/L-916	510.1	8	4080.8		0.0		0.0		0.0		0.0		0.0
318/L-916	519.1	6	3114.6		0.0		0.0		0.0		0.0		0.0
319/L-917	329.4	27	8893.8		0.0		0.0		0.0		0.0		0.0
320/L-917	270.9	7	1896.3		0.0		0.0		0.0		0.0		0.0
321/L-917	192.9	10	1929.0		0.0		0.0		0.0		0.0		0.0
322/L-918	163.9	35	5736.5		0.0		0.0		0.0		0.0		0.0
323/L-918	221.3	7	1549.1		0.0		0.0		0.0		0.0		0.0
324/L-918	131	21	2751.0		0.0		0.0		0.0		0.0		0.0
325/L-919	144.3	20	2886.0		0.0		0.0		0.0		0.0		0.0
326/L-919	124.9	100	12490.0		0.0		0.0		0.0		0.0		0.0
327/L-920			0.0		0.0		0.0		0.0		0.0		0.0
328/L-921			0.0		0.0		0.0		0.0		0.0		0.0
329/L-922			0.0		0.0		0.0		0.0		0.0		0.0
330/L-923			0.0		0.0		0.0		0.0		0.0		0.0
331/L-923			0.0		0.0		0.0		0.0		0.0		0.0
332/L-924			0.0		0.0		0.0		0.0		0.0		0.0
333/L-924			0.0		0.0		0.0		0.0		0.0		0.0
334/L-925			0.0		0.0		0.0		0.0		0.0		0.0
335/L-925			0.0		0.0		0.0		0.0		0.0		0.0
336/L-926			0.0		0.0		0.0		0.0		0.0		0.0
337/L-926			0.0		0.0		0.0		0.0		0.0		0.0
338/L-926			0.0		0.0		0.0		0.0		0.0		0.0
339/L-927			0.0		0.0		0.0		0.0		0.0		0.0
340/L-927			0.0		0.0		0.0		0.0		0.0		0.0
341/L-927			0.0		0.0		0.0		0.0		0.0		0.0
342/L-928			0.0		0.0		0.0		0.0		0.0		0.0
343/L-928			0.0		0.0		0.0		0.0		0.0		0.0
Total:		**288**	**64426.4**	**212**	**41751.7**	**388**	**92593.0**	**114**	**34127.0**	**414**	**121574.2**	**389**	**110632.3**

	Zone 2u	Zone 2l	Zone 3a	Zone 3b	Zone 3c	Zone 4
Total cell area by sub-zone (sq. m.)	64426.4	41751.7	92593.0	34127.0	121574.2	110632.3
Sub-zone area (sq. m.)	3576232.5	595742.3	1595136.8	794032.6	3455424.1	4999088.3
Percentage of vegetated sub-zone area	1.8%	7.0%	5.8%	4.3%	3.5%	2.2%

TOTAL PROJECT DATA

		sq.m	hectares	acres	sq mile
Total number of cells:	1805				
Total project area (sq. m.)	15015656.6	15015656.6	1501.6	3708.9	5.8
Total project cell area (sq. m.)	465104.6	465104.6	46.5	114.9	0.2
Total percentage of project vegetated	3.1%				

	Area (sq. m.)	Area (acres)	Cell Area (sq.m.)	Cell area (acres)	Coverage
Zone 2	4171974.8	1030.5	106178.1	26.2	2.5%
Zone 3	5844593.5	1443.6	248294.2	61.3	4.2%
Zone 4	4999088.3	1234.8	110632.3	27.3	2.2%
				114.9	

Appendix 1. Plant cell coverage calculation sheet (all figures in square meters unless otherwise noted)

WHRP Plant Quantities

Plant Symbol	Plant Name	Size/Type	Quantity Z1	Quantity Z2u	Quantity Z2l	Quantity Z3a	Quantity Z3b	Quantity Z3c	Quantity Z4	Quantity Z5	Total Quantity
Trees											
Ag	Acacia gerrardii	15 gal. cont.	0	0	483	406	296	1485	1214	0	3884
Ag30	Acacia gerrardii	30mm caliper									0
An	Acacia nilotica	15 gal. cont.	0	1201	471	495	237	1060	996	0	4460
An30	Acacia nilotica	30mm caliper									0
At	Acacia tortilis	15 gal. cont.	0	1928	1137	503	320	1869	1785	0	7542
At30	Acacia tortilis	30mm caliper	0	485	863	201	0	720	1710	0	3979
Pd	Phoenix dactylifera	30mm caliper	0	420	0	969	1940	910	395	0	4634
Ta	Tamarix aphylla	15 gal. cont.	0	78	12	36	36	168	90	0	420
Ta30	Tamarix aphylla	30mm caliper									0
Tn	Tamarix nilotica	15 gal. cont.	0	164	392	252	126	378	462	0	1774
Tn30	Tamarix nilotica	30mm caliper									0
Zs-c	Zizyphus spina-christi	15 gal. cont.	0	0	118	222	134	521	333	0	1328
Zs-c30	Zizyphus spina-christi	30mm caliper									0
										Total Trees:	**28021**
Shrubs											
Ae	Acacia ehrenbergiana	5 gal. cont.	0	0	360	80	140	1160	1080	0	2820
Ang	Anvillea garcini	5 gal. cont.	0	0	20	50	30	120	90	0	310
Ah-a	Artemisia herb-alba	5 gal. cont.	0	0	0	0	0	0	0	0	0
As	Astragalus spinosus	5 gal. cont.	0	0	247	117	78	780	728	0	1950
Ah	Atriplex halimus	5 gal. cont.	0	754	0	0	0	0	0	0	754
Cap	Calotropis procera	5 gal. cont.	0	0	357	249	117	378	450	0	1551
Cs	Capparis spinosa	5 gal. cont.	0	0	168	99	80	250	285	0	882
Fc	Francoeria crispa	5 gal. cont.	0	64	28	126	112	266	98	0	694
Hp	Haloxylon persicum	5 gal. cont.	0	68	0	0	0	0	0	0	68
He	Hammada elegans	5 gal. cont.	0	0	44	237	241	626	388	0	1536
Ld	Lavandula dentata	5 gal. cont.	0	1237	487	236	177	1134	1217	0	4488
Lp	Leptadenia pyrotechnica	5 gal. cont.	0	0	725	652	385	2890	2841	0	7493
S-Lp	Leptadenia pyrotechnica	seeds									0
Ls	Lycium shawii	5 gal. cont.	0	0	66	114	126	468	423	0	1197
Ob	Ochradenus baccatus	5 gal. cont.	0	0	403	257	123	702	740	0	2225
S-ob	Ochradenus baccatus	seeds									0
Re	Rhanterium eppaposum	5 gal. cont.	0	684	279	65	94	324	355	0	1801
S-Re	Rhanterium eppaposum	seeds									0
Rs	Rhazya stricta	5 gal. cont.	0	1373	483	408	377	1425	988	0	5054
S-Rs	Rhazya stricta	seeds									0
Rm	Rhynchosia minima	3 gal. cont.	0	877	114	133	57	912	855	0	2948
S-Rm	Rhynchosia minima	seeds									0
Tp	Teucrim polium	5 gal. cont.	0	0	46	179	149	388	175	0	937
Zs	Zilla spinosa	5 gal. cont.	0	0	140	168	54	270	282	0	914
Zc	Zygophyllum coccineum	5 gal. cont.	0	0	180	121	205	1012	1026	0	2544
S-Zc	Zygophyllum coccineum	seeds									0
										Total shrubs:	**40166**
Grasses											
Ao	Aristida obtusa	3 gal. cont.	0	0	312	221	279	1568	1427		3807
Cc	Cymbopogon commutatus	3 gal. cont.	0	0	0	0	0	0	0		0
Cp	Chrysopogon plumulosus	3 gal. cont.	0	0	502	471	519	2121	1683		5296
Hh	Hyparrhenia hirta	3 gal. cont.	0	1628	1132	824	510	2055	1808		7957
Lh	Lasiurus hirsutus	3 gal. cont.	0	3773	986	861	542	2232	1911		10305
Pt	Panicum turgidum	3 gal. cont.	0	2418	230	248	170	569	401		4036
S-Pt	Panicum turgidum	seeds									0
Ped	Pennisetum divisum	3 gal. cont.	0	0	1046	96	770	4068	3222		9202
S-Ped	Pennisetum divisum	seeds									0
Sp	Stripagrostis plumosa	3 gal. cont.	0	0	400	167	243	1771	1535		4116
										Total grasses:	**44719**
Seeded grasses area (acres)				28.804646				3.34685	1.371591		**33.523087**
Seeded perennials (acres)				1.379989							**1.379989**
Sod area (acres)						1.252784					**1.252784**

Appendix 2. Planting schedule and calculation sheet (data from Moriyama & Teshima Planners