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MONITORING AND ANALYSIS OF EROSION AND DEPOSITION IN THE DESERT KNOLLS WASH

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MONITORING AND ANALYSIS OF EROSION AND DEPOSITION IN THE DESERT KNOLLS WASH

A Project

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in

Earth and Environmental Sciences

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by

Samson Rajan Lamech

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Approved by:

Dr. Norman Meek, Committee Chair, Geography and Environmental Studies

Dr. Brett Stanley, Committee Member

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ABSTRACT

The goal of this Project was to monitor and measure ongoing changes in the geomorphology of one reach of The Desert Knolls Wash (DKW), an unstable ephemeral stream channel in Apple Valley, California. The DKW flows into the Mojave River just upstream of the Upper Mojave Narrows, a historic site that has been the focus of recorded human activity in the region since 1776.

Two surveyed cross-sections were established for three periods of time between November 2012 and November 2014 which were to be re-measured after significant flows. However, owing to the persistent drought in the location, there were no significant changes observed. Aerial photos from 1938 to 2005 and historic photos from 1919 covering the DKW were studied to note the increase in urban density.

The project has established baseline field measurements to document the magnitude and timing of the ongoing channel changes as well as predict what will happen over the next two decades if measures are not taken to stabilize the channel permanently.

ACKNOWLEDGMENTS

I would like to express my sincerest gratitude to the members of my graduate committee: Dr. Norman Meek, Chair, Dr. Brett Stanley, and Dr. Rajrani Kalra, for the support and encouragement throughout my research project.

I would also like to thank Matthew D. Huffine, an instructor at the Lewis Center in Apple Valley for his support and assistance during this project. I would like to express my gratitude to the staff at the Mojave Water Agency: Brian Hammer and Curt James, for their support and assistance with GIS during this research project.

I would also like to thank my family and friends for the encouragement during the research project. Thank you all.

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CHAPTER ONE

INTRODUCTION

Background and Purpose

The purpose of this project was to monitor and measure ongoing changes in the geometry of one reach of an unstable ephemeral stream channel located in Apple Valley, California. This report will discuss the changes in the channel over the past century and discuss the probable causes for periodic changes in erosion and deposition along the channel.

During a visit to the Lewis Center's Mojave River Campus in the summer of 2011, I met some friends on a plot of ground adjacent to the Desert Knolls Wash (DKW) that was slated for development for athletic fields in the near future. They shared a concern they had. While discussing the Wash, some of them were predicting that the channel would soon meander south, crossing into the site that was to be developed into athletic fields As a student of Environmental Science, I took an interest in the subject and wanted to study the impact that increased upstream urban runoff was having on the school's property and the local environment. I envisaged various reasons that might be causing the DKW to encroach upon the site of the school's proposed athletic fields. One of the reasons could be the result of increased urbanization near the wash. A review of historical maps of the area would reveal whether the wash was natural or highly modified by urban runoff. Visits to the Apple Valley city offices and San

Bernardino County offices were necessary to find data and records that might indicate the causes for the changes in the wash. Reviewing the maps accessed at the offices provided convincing evidence that the present impacts on the DKW were likely the result of urban runoff, which in turn, was accelerating the changes. The rapid urbanization of the area is accompanied by growing impermeable surfaces and increased runoff, which have been causing changes in the DKW.

The DKW is located in the Mojave River watershed, as shown in Fig. 1 and Fig. 2, a basin which encompasses approximately 4,500 square miles located entirely within San Bernardino County (Stormwater Management Program for the Mojave River Watershed, 2003). In wet years, such as 1916 and 1938, the Mojave River flow can reach all of way to Death Valley. The Mojave River is the longest drainage system in the western part of the Mojave Desert which receives its main water supply from 217 square miles of headwaters in the northern portion of the San Bernardino Mountains (Water Supply Assessment, 2009).

The Mojave River channel, through both surface and subsurface flow, transects the watershed a linear distance of approximately 120 miles to its sedimentological terminus at Silver Dry Lake near the community of Baker. In a discussion with the staff at the Lahontan Regional Water Quality Control Board in Victorville (Oral communication, Cass and Zimmerman, 2012), they stated that just like other ephemeral streams in the region, the DKW performs numerous

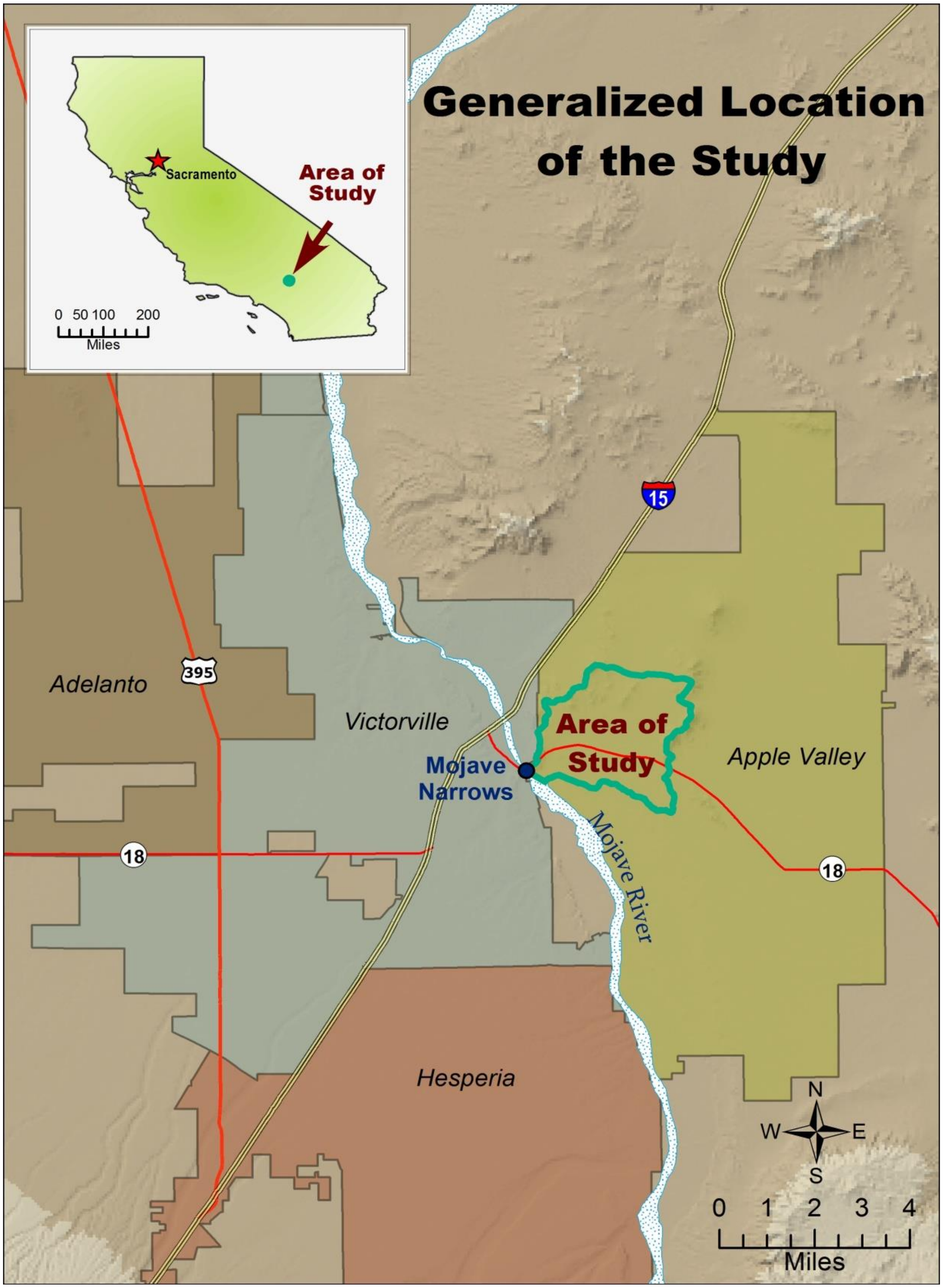

Figure 1. Generalized Location of the Study

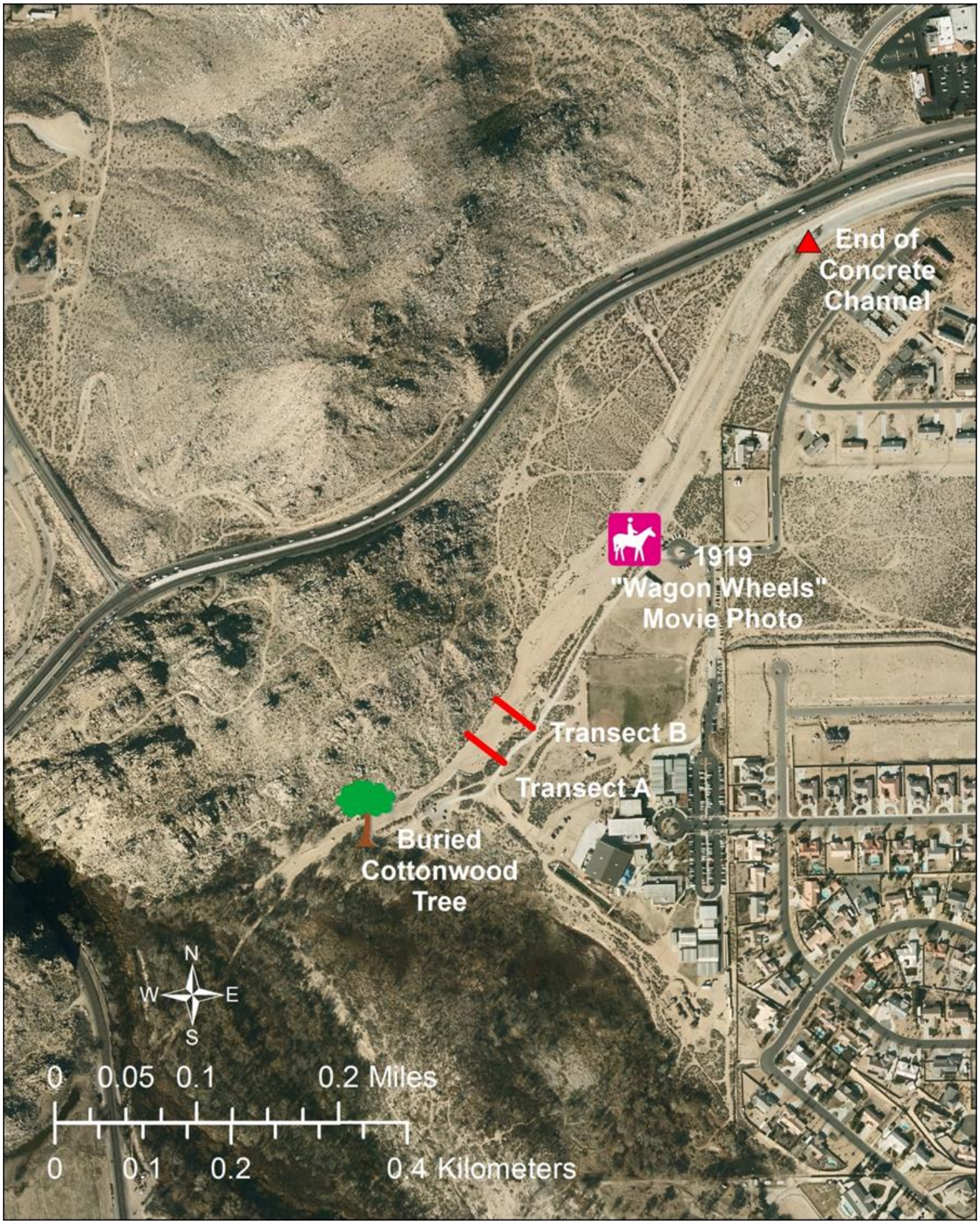

Figure 2. Detailed Map of the Study Area

hydrologic and water quality functions which include surface and subsurface water storage.

According to chapter 2 in the document: Water Quality Control Plan for the Lahontan Region, this area is classified as hydrologic unit 628.20 and it is deemed, “minor surface waters.” Some of the present and potential beneficial uses listed in this basin plan are: municipal and domestic water supply, agricultural supply, ground water recharge, hydropower generation, recreation, warm and cold freshwater habitat, and wildlife habitat. (State of California Regional Water Quality Control Board, Lahontan Region, 1994)

DKW naturally provides for sediment transport and deposition, water storage and conveyance, filtering, nutrient cycling, and facilitates wildlife movement and migration (State of California Regional Water Quality Control Board, Lahontan Region, 1994. Over a period of time, the DKW has been encroached upon by residential and business development. The San Bernardino County Flood Control has proposed various plans to control flows in a portion of the Wash approximately one and a half miles upstream from its confluence with the Mojave River. The original plans submitted by the County suggested straightening the channel and lining it with concrete in a three-phased approach such as lower, middle, and upper reaches (Plans for construction on Desert Knolls Wash; Mojave River to Apple Valley road. Work order no. F01057, 2012). In 1993, the middle reach of the project was completed which consisted of a fully lined concrete channel. The upper reach, and the lower reach which is the focus of this study, have not yet been constructed.

San Bernardino County's plans have been revised a number of times owing to protecting the water quality and beneficial uses of the DKW. During 2012, the County proposed three conceptual alternatives for the DKW improvement project. All three conceptual plans proposed were designed to protect the adjacent properties from the 100-year storm events (Plans for construction on Desert Knolls Wash; Mojave River to Apple Valley road. Work order no. F01057, 2012). The first concept proposed was the, "Low Flow Side Channel," which is a concrete channel with an adjacent and parallel, earth-bottomed low flow channel. This concept would enable low flow infiltration of urban runoff facilitating pollutants to settle out before the flow reaches wetlands near its confluence with the Mojave River. This proposal also included natural and permeable materials which would encourage natural vegetation. The drawback of this concept would be that a major portion of the channel would involve concrete and cause high velocity flows affecting special aquatic resources and special status species (Plans for construction on Desert Knolls Wash; Mojave River to Apple Valley road. Work order no. F01057, 2012). The second concept proposed was the "Gabion Drop Structures" which comprises an earthen channel along with intermittent gabion mattress structures. This plan would reduce sediment production relative to the present conditions benefiting the riparian/wetland habitat. Like the first concept, this plan would also use natural materials to benefit plant and wildlife species. The third concept proposed by the County was the “Boulder Stabilizer” plan which is a natural/earthen bottom channel along with natural side slopes and boulder stabilizers. This plan would facilitate more percolation and also groundwater recharge. This configuration would allow for infiltration of the urban runoff where pollutants and sediment could settle out before reaching the wetlands. The Lahontan Regional Water Quality Board has recommended that the County consider a combination of the Gabion Drop Structures and Boulder Stabilizer conceptual plans for the DKW improvement project (Plans for construction on Desert Knolls Wash; Mojave River to Apple Valley road. Work order no. F01057, 2012).

This project was conducted in an effort to quantify the effect of upstream land use and development practices on the DKW channel. This, in turn, could have implications on how the present land owner, the Lewis Center for Educational Research, plans to develop their property along the channel. Changes in channel flows into the Mojave River above the Upper Narrows could also inundate and bury historic sites that have been the focus of recorded human activity in the region since 1776. After the middle segment of the channel was encased in an engineered cement channel in 1993, the unarmored channel just downstream degraded several meters, exposing bedrock just downstream of the cemented channel end. Within the area that was studied, one channel bank and a sewer outlet have been armored with giant boulders owing to the rapid changes in the channel. Downstream of this location the stream channel has aggraded several meters, partially burying some large trees which is highlighted in chapter 3.

Scope and Significance of the Study

This project investigates the geomorphic stability of DKW. The project includes two cross-section studies of the channel measured during three periods of time between November 2012 and November 2014. Moreover, aerial photographs from 1939 to 2012 were examined as well as changes evident in photographs of events in the wash over about 10 years were used.

Aim and Objective

The objective of this project is to investigate what processes have caused DKW to change. One of the primary objectives of this study is to find out if increased urbanization in the areas drained by this channel is causing changes in the DKW cross-section.

CHAPTER TWO

LITERATURE REVIEW

Studies on the geomorphic effects of increased urbanization have been made in the past. One such study was conducted by White and Greer (2006). They researched Los Penasquitos Creek in Southern California from the years 1966 to 2000. During the scope of their study urban land use had increased from 9% to 37% (White and Greer, 2006). Concurrent to this urban growth there were significant increases in yearly median and minimum discharges along with dry season runoff and the magnitude of flooding. The stream channel also experienced geomorphic changes. Along with using stream gage records to measure changes in the streamflow, White and Greer used aerial photographs to document the changes in the watershed. Urbanization results in more impermeable surfaces that over time, reduces infiltration and increases runoff. White and Greer used aerial photos to analyze the watershed from 1928 to 2000 by scanning and geo-referencing the digital imagery to study the changes in the watershed. According to their findings, runoff increased in Penasquitos Creek 200 to 500 % as the percent of basin-wide impermeable surfaces increased by just 10%. Moreover, they found that streams in the area had changed significantly because of the increase in urban runoff where ephemeral drainages have now become perennial streams.

This phenomenon was again made evident when (Suriya and Mudgal, 2012) conducted a study in Chennai, India which compared flood peaks before and after development of the area, and attributed the changes to urbanization of the watershed that encompasses the city of Chennai, in southern India. They found that the risk of flooding is increased by urbanization in floodplain areas and resulted in environmental damage. A continuous increase in the amount of impermeable surfaces affected the natural water balance as less infiltration caused more runoff resulting in floods even when there was less rain over shorter periods. They concluded that the large increase in population and increased urbanization were the prime reasons for flooding. The watershed had large built-up areas and had undergone rapid urbanization between the years 1979 and 2005. Their findings revealed that agricultural land covered about 24% of the basin in 1976 and decreased to 15% by 2005, while the built up areas had increased from about 70 sq km in 1976 to over 107 sq km in 2005. Also the plantation area decreased from 11.38 sq km in 1976 to a mere 4.12 sq km in 2005 (Suriya and Mudgal, 2012).

In another study, Chin (2006), suggested that river channels in areas that support human population proceed through stages. One of the stages described are the impacts of urbanization. She called this third and last stage, ‘urban development’. Chin studied the impact of urban development on landscapes by collecting data from over 100 studies which collectively indicate that channels tend to enlarge from two or three times up to fifteen times their original size as a result of urbanization. She described how impermeable surfaces such as rooftops and gutters caused increased runoff resulting in increased erosion. As more runoff follows, widening of the channel takes place. Chin's study produced evidence that urbanization/urban development caused a substantial increase in the production of fluvial sediments (Chin, 2006). As indicated in Fig. 3, an increase in impervious surfaces will lead to increased runoff. This factor, along with decreased sediment production, will give rise to channel erosion. Her analysis indicated that urban development resulted in higher and more frequent floods; as the area covered by impermeable surfaces increases, so did runoff.

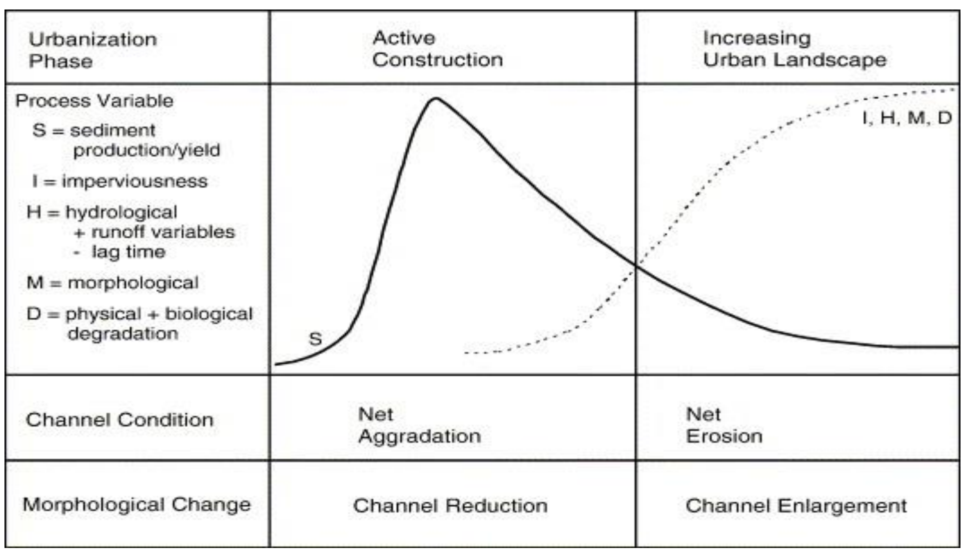

Figure 3. Graph Showing Increase in Impervious Surfaces Leading to Increased Runoff (Chin, A. Urban transformation of river landscapes in a global context, *Geomorphology* **2006** 79(3-4), 460–487.

Studies were also conducted by Ahmadi et al. (2007) using the Water Erosion Prediction Project (WRPP) model. They used this model to test and predict changes in runoff and sediment yield. Comparative studies with predictions and then measurements indicated that the project underestimated by 23% the sediment volumes, and overestimated total runoff to 27% (see Table 1).

Table 1. Average of Annual Measured and Predicted Runoff and Sediment Volumes for the Whole Orazan Catchment

	Average measured volume (m^3 /YEAR)	Average predicted volume (m^3 /YEAR)
Sediment	7000	5389.9 (-23%)
Runoff	2487685	3159359 (+27%)

The conclusion of this case study conducted in the Orazan Watershed of Iran between 1996 and 2005, pointed to changes in land use that followed rapid urbanization which was a significant factor leading to increased erosion and transportation of sediment (Ahmadi et al., 2007).

CHAPTER THREE

RESEARCH METHODOLOGY

To better understand the scope of the changes that have occurred in the DKW study area, a variety of historic pictures and maps were analyzed. Aerial photos were obtained on November 05, 2012 from San Bernardino County Flood Control to study the changes in the DKW drainage basin. Of the available aerial photos, the 1938, 1969, 1979, 1994, and the 2005 aerial photos were relevant to my study (see Figs. 4 to 8).

Information from the 1919 feature film, “Wagon Tracks,” a silent movie that was shot at the location of the study site was used in the project. Two frames were copied from the movie and compared with modern pictures of the area as shown in Fig. 9 and Fig. 10.

Photographs taken in 2001 near a particular cottonwood tree were obtained from the Lewis Center for Educational Research and compared with a photograph that was taken in 2012. The comparison shows sediment buildup of at least 1.5 meters in eleven years as seen in Fig.11 and Fig.12. These pictures show that the base of the tree trunk has been buried by sediment carried by the aggrading channel. The DKW channel drains a significant portion of a rapidly urbanizing watershed known as the Desert Knolls drainage basin.

Three surveys of the DKW were conducted between November 2012 and November 2014 to determine the impacts.

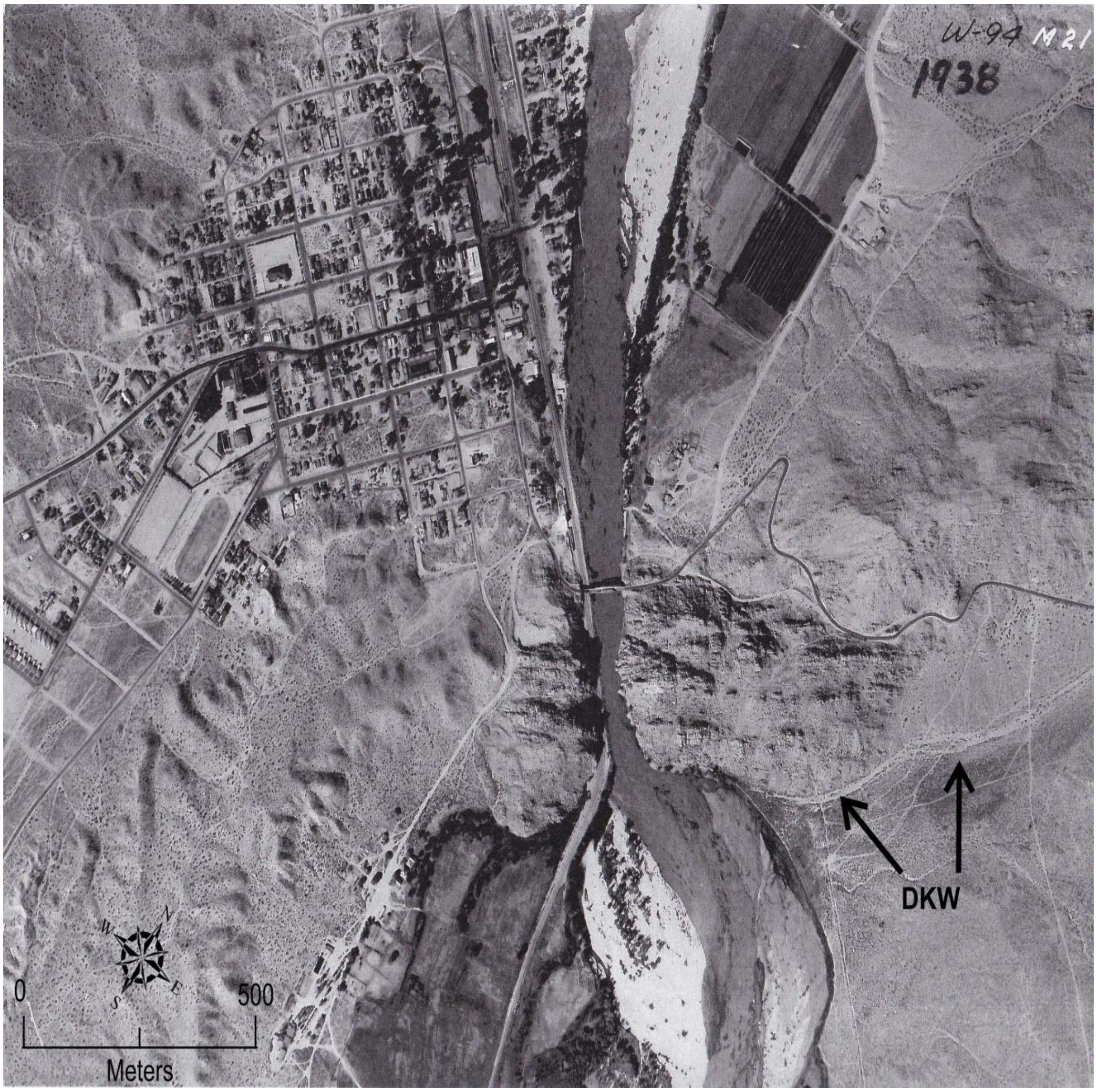

Figure. 4. Aerial Photo Dated 1938 Showing Sparse Urbanization (San Bernardino County Flood Control, Department of Public Works, 2013).

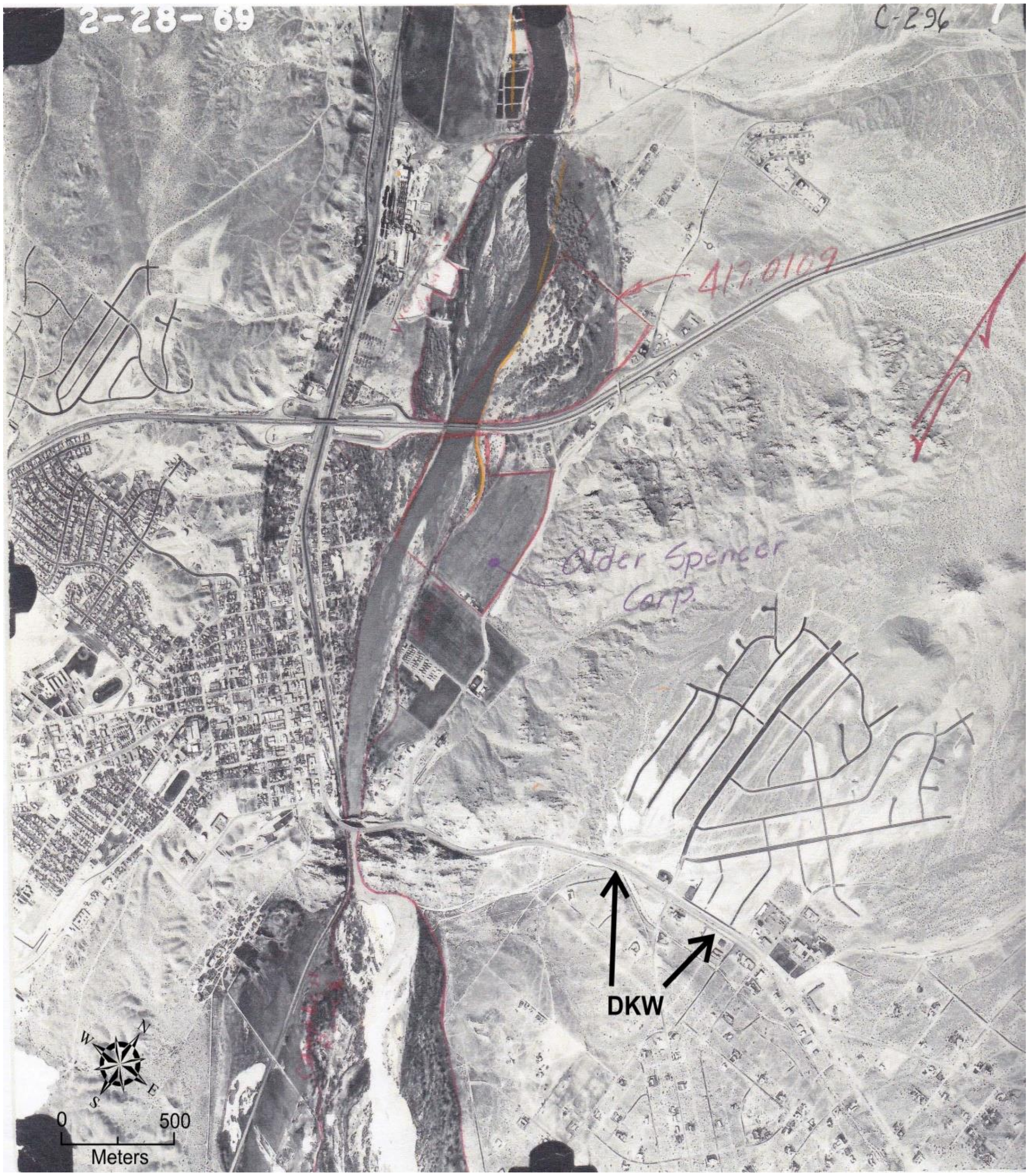

Figure 5. Aerial Photo Dated 1969 Showing Increasing Urbanization (San Bernardino County Flood Control, Department of Public Works, 2013).

Figure. 6. Aerial Photo Dated 1979 Showing More Urbanization.
Notice the absence of a concrete channel (San Bernardino County Flood Control, Department of Public Works, 2013).

Figure 7. Aerial Photo Dated 1994 Showing More Urbanization.
Notice the concrete channel has been added (San Bernardino County Flood Control, Department of Public Works, 2013).

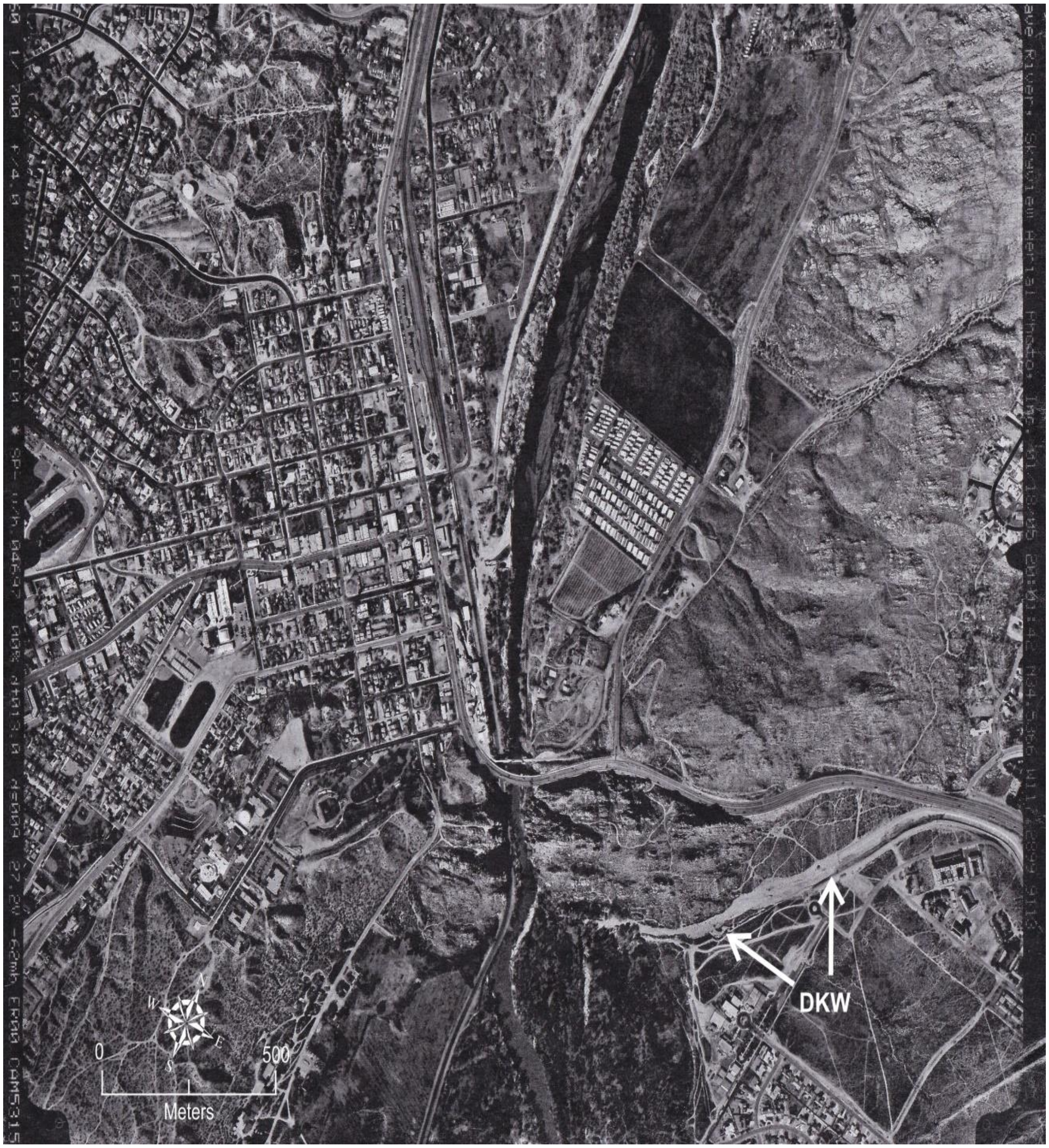

Figure 8. Aerial Photo Dated 2005 Showing Increased Urbanization (San Bernardino County Flood Control, Department of Public Works, 2013).

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1919 **2010**

Figure 9. Comparison of 1919 and 2010 Photos
Notice the substantial degradation seen between the two time periods (1919 clip from the silent movie “Wagon Tracks” by Grapvine Video).

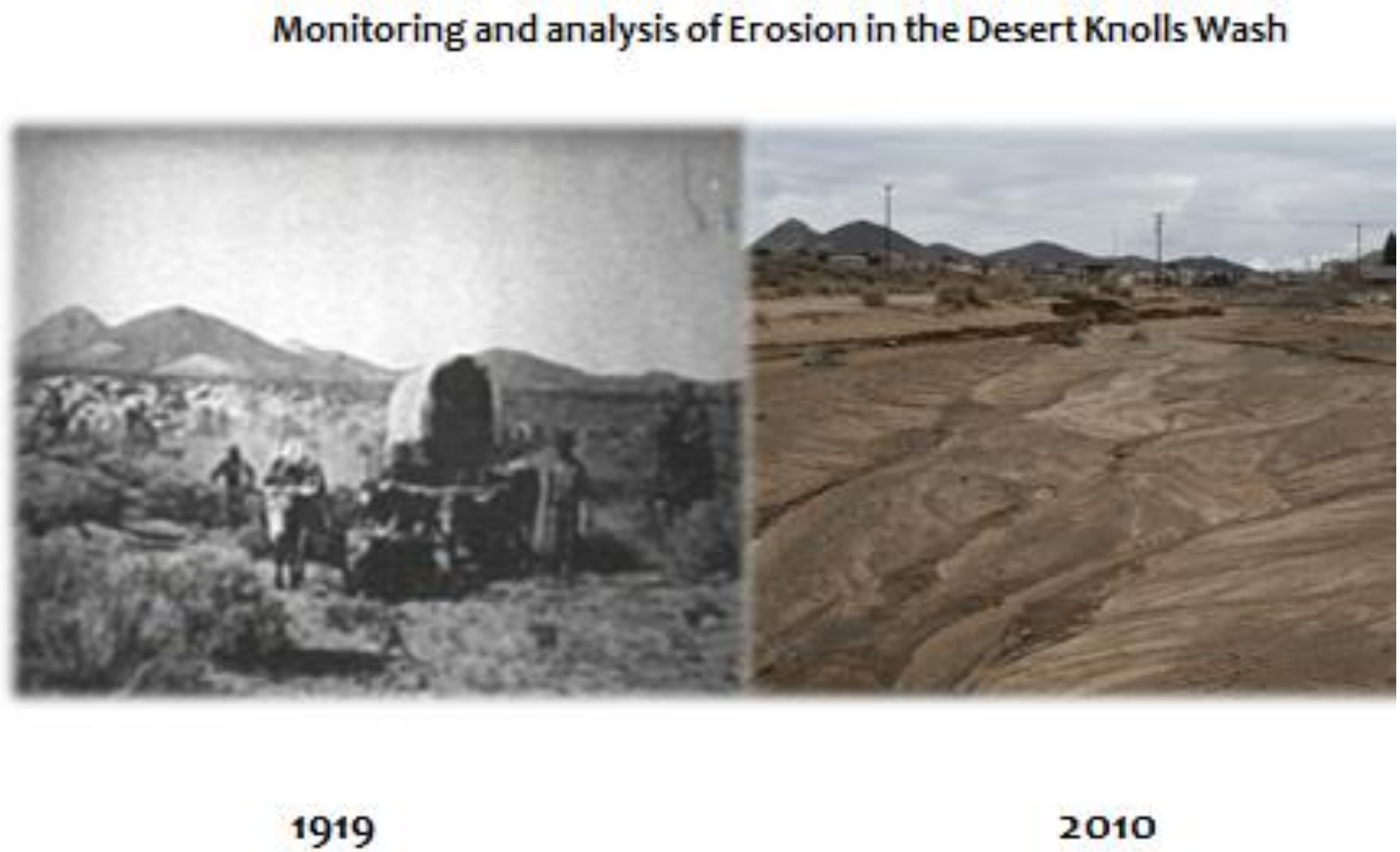

Figure 10 Comparison of 1919 and 2010 Photos
Notice the substantial degradation seen between the two time periods (1919 clip from the silent movie “Wagon Tracks” by Grapvine Video).

Figure 11. 2012 Photo Showing Sediment Accumulation from 2001. Sediment accumulation of more than 1.5 m between the two time periods

Figure 12. 2012 Photo of Tree Trunk Buried by Sediment from the Aggrading Stream

A USGS 7.5 minute topographic map of the Victorville Quadrangle was used to map out the drainage area and manually plot the drainage basin boundary of the DKW drainage basin before scanning and digitizing for use in GIS.

Historical Changes Based on Photography

Aerial photographs of the project area from the Mojave Water Agency for 1969, 2000, and 2012 were obtained on February 5, 2013 to study and measure the increasing urban growth in the drainage basin.

CHAPTER FOUR

MAP AND PHOTO ANALYSES

In this section of study, aerial photographs from 1969, 2000 and 2012 were collected, compared, and analyzed to determine progressive growth in urbanization. Monitoring changes in the DKW cross-section was started in May 2012 under the guidance of Prof. Norman Meek of the Geography Department at California State University, San Bernardino. The equipment used in this procedure was a LUX Telescopic Level with a magnification of 32x; a 7.5 m telescopic rod and 100 m measuring tape (see Fig. 13).

Figure 13. Photo of Telescopic Level 32x and 7.5 Telescopic Rod.

Two cross-sectional channel transects (width) were established and then measured (see Tables 2 to 7) to record base-line conditions in order to monitor future changes in the channel. This is a procedure similar to what was done by Schumm et al. 1987, p.113-119.

Table 2. Cross Section Data for Transect A

11/2/2012	Cross Section A (North)		
Distance	**Foresight**	**Elevation**	**Description**
0.00	1.54	823.87	Ref. Point (Elev. Per GPS)
4.90	1.59	823.82	Edge of Gravel Road
7.20	1.55	823.86	Center of Gravel Road
9.70	1.66	823.75	West Edge of Gravel Road
10.40	1.60	823.81	Top of Berm
11.40	1.68	823.73	Existing Natural Ground (NG) Terrace
15.80	2.55	822.86	NG Top Edge of Terrace (East Edge)
15.90	2.45	822.96	East Base of Upper channel
22.60	2.86	822.55	Center of Upper Channel
32.00	2.31	823.10	West Edge of Upper Channel
33.80	3.43	821.98	East Bottom Lower Channel (Main Channel)
36.50	3.33	822.08	Main Channel Grade Break
36.80	3.39	822.02	Main Channel
49.00	3.32	822.09	Center of Bottom Channel
61.70	3.22	822.19	Channel Bottom West Side
62.40	3.34	822.07	West Edge of Channel Top
64.30	2.24	823.17	West Top of Main Channel
67.40	1.98	823.43	NG Base of Rock Slope

Table 3. Cross Section Data for Transect B

11/2/2012	Cross Section B (South)		
Distance	**Foresight**	**Elevation**	**Description**
0.00	1.60	814.73	Ref. Point (Elev. Per GPS)
5.50	1.83	814.50	Edge of Channel Top
5.60	2.08	814.25	Edge of Channel Bottom
6.50	2.02	814.31	At the marked pole (Bottom of Channel)
11.60	1.90	814.43	N.G. Bottom of Channel
17.60	1.79	814.54	N.G. Bottom of Channel (Center)
23.00	1.83	814.50	N.G. Bottom of Channel
27.70	1.78	814.55	Edge of Channel Bottom
29.90	1.71	814.62	Top of Slope
31.90	1.25	815.08	Top of slope (Edge of Walking Trail)
33.50	1.33	815.00	Center of Trail
35.00	1.08	815.25	Edge of Trail (Top of Slope)
36.80	0.30	816.03	Top of Slope
38.10	0.17	816.16	Edge of Power Pole

Table 4. Cross Section Data for Transect A

11/12/2012	Cross Section A (North)		
Distance	**Foresight**	**Elevation**	**Description**
0.00	1.44	823.87	Ref. Point (Elev. Per GPS)
4.90	1.49	823.82	Edge of Gravel Road
7.20	1.46	823.85	Center of Gravel Road
9.70	1.58	823.73	Other edge of Gravel Road
10.40	1.51	823.80	Top of Berm
11.40	1.72	823.59	N.G Terrace
15.80	1.92	823.39	Top Edge of Upper Channel (East Edge)
15.90	2.49	822.82	East Base of Upper Channel
22.60	2.90	822.41	Center of Upper Channel
32.00	2.34	822.97	West Edge of Upper Channel
33.80	3.40	821.91	East Bottom Lower Channel (Main Channel)
36.50	3.27	822.04	Main Channel Gread Break
36.80	3.40	821.91	Grade Break Main Channel
49.00	3.36	821.95	Center of Bottom Channel
61.70	3.25	822.06	Channel Bottom West Side
62.40	2.35	822.96	West Edge of Channel Top
64.30	2.29	823.02	Center Line of Walking Trail
67.40	1.92	823.39	NG Base of Rock

Table 5. Cross Section Data for Transect B

11/12/2012	Cross Section B (South)		
Distance	**Foresight**	**Elevation**	**Description**
0.00	1.65	814.73	Ref. Point (Elev. Per GPS)
5.50	1.93	814.45	Edge of Channel Top
5.60	2.12	814.26	Edge of Channel Bottom
6.50	2.15	814.23	At the marked pole (Bottom of Channel)
11.60	1.95	814.43	N.G. Bottom of Channel
17.60	1.84	814.54	N.G. Bottom of Channel (Center)
23.00	1.87	814.51	N.G. Bottom of Channel
27.70	1.93	814.45	Edge of Channel Bottom
29.90	1.76	814.62	Top of Slope
31.90	1.26	815.12	Top of slope (Edge of Walking Trail)
33.50	1.33	815.05	Center of Trail
35.00	1.09	815.29	Edge of Trail (Top of Slope)
36.80	0.04	816.34	Top of Slope
38.10	0.02	816.36	Edge of Power Pole

Table 6. Cross Section Data for Transect A

11/8/2014	Cross Section A (North)		
Distance	**Foresight**	**Elevation**	**Description**
0.00	1.41	823.87	Ref. Point (Elev. Per GPS)
4.90	1.45	823.86	Edge of Gravel Road
7.20	1.47	823.84	Center of Gravel Road
9.70	1.56	823.75	Other edge of Gravel Road
10.40	1.51	823.80	Top of Berm
11.40	1.70	823.61	N.G Terrace
15.80	1.94	823.37	Top Edge of Upper Channel (East Edge)
15.90	2.51	822.80	East Base of Upper Channel
22.60	2.92	822.39	Center of Upper Channel
32.00	2.33	822.98	West Edge of Upper Channel
33.80	3.46	821.85	East Bottom Lower Channel(Main Channel)
36.50	3.25	822.06	Main Channel Gread Break
36.80	3.43	821.88	Grade Break Main Channel
49.00	3.36	821.95	Center of Bottom Channel
61.70	3.28	822.03	Channel Bottom West Side
62.40	2.35	822.96	West Edge of Channel Top
64.30	2.32	822.99	Center Line of Walking Trail
67.40	1.92	823.39	NG Base of Rock

Table 7. Cross Section Data for Transect B

11/8/2014	Cross Section B (South)		
Distance	**Foresight**	**Elevation**	**Description**
0.00	1.65	814.73	Ref. Point (Elev. Per GPS)
5.50	1.96	814.42	Edge of Channel Top
5.60	2.14	814.24	Edge of Channel Bottom
6.50	2.11	814.27	At the marked pole (Bottom of Channel)
11.60	1.99	814.39	N.G. Bottom of Channel
17.60	1.84	814.54	N.G. Bottom of Channel (Center)
23.00	1.88	814.50	N.G. Bottom of Channel
27.70	1.93	814.45	Edge of Channel Bottom
29.90	1.75	814.63	Top of Slope
31.90	1.28	815.10	Top of slope (Edge of Walking Trail)
33.50	1.30	815.08	Center of Trail
35.00	1.10	815.28	Edge of Trail (Top of Slope)
36.80	0.05	816.33	Top of Slope
38.10	0.03	816.35	Edge of Power Pole

The northern Transect "A" (see Tables 2, 4 and 6) is located between UTM 474247mE, 3821409mN and 474281mE, 3821384mN at an approximate elevation of 847 meters above sea level. The second, a southern transect "B," (see tables 3, 5. and 7) which begins at UTM 474091mE, 3821258mN and ends at 474089mE, 3821288mN is at an elevation of 839.41 meters above sea level. Surveys were conducted on November 02, 2012, November 12, 2012, and November 8, 2014. However, the results of the study did not reveal significant channel changes as there were no major flood events or substantial rainfall during the 30-month period of study.

As the project site is part of the Lewis Center for Educational Research, the staff from this school was consulted during the research. Photographs taken in 2001 were used to determine how much sediment had accumulated since then. An old cottonwood tree (*Populus fremontii*) as shown in Fig. 11 and Fig. 12 at the proposed site was used to show how its trunk has been buried by sediments. According to an oral interview with Matt Huffine during the summer of 2011 (Oral Communication, M.Huffine, July 2011), the particular branch marked on the cottonwood tree (see Fig. 11) reveals that it was situated 3.72 meters above the ground in the photograph taken in 2001. Now the branch stands about 2.17 meters above the ground level, an indication of about 1.55 meters of sediment accumulation at this spot between the years 2001 and 2012. Two other photographs Figs. 14 and 15 reveal branches buried because of sediment accumulation.

Figure 14. Photo of Partly Buried Cottonwood Branch. Aggradation of the Desert Knolls Wash has buried this branch of the cottonwood tree. Jan 26, 2013.

Figure 15. Close-up Photo of the Partly Buried Cottonwood Branch. The partly buried branch now looks like a root. Jan 26, 2013.

Aerial photos of the Desert Knolls basin in the years 1938, 1969, 1979, 1994, and 2005 were used to study the changes in the drainage basin. To define the drainage basin, 7.5 minute topographic maps of the project area were used. The basin boundary was scanned and digitized for use in GIS. A flatbed Scan Tech Microdesk 9800 XL Scanner was utilized to scan at a resolution of 2400 dpi, the 1969, 2000, and 2012 aerial photographs (see Figs. 16 to 18). With the help of ESRI software (ARCMAP 10.0), all three aerial photographs were digitized.

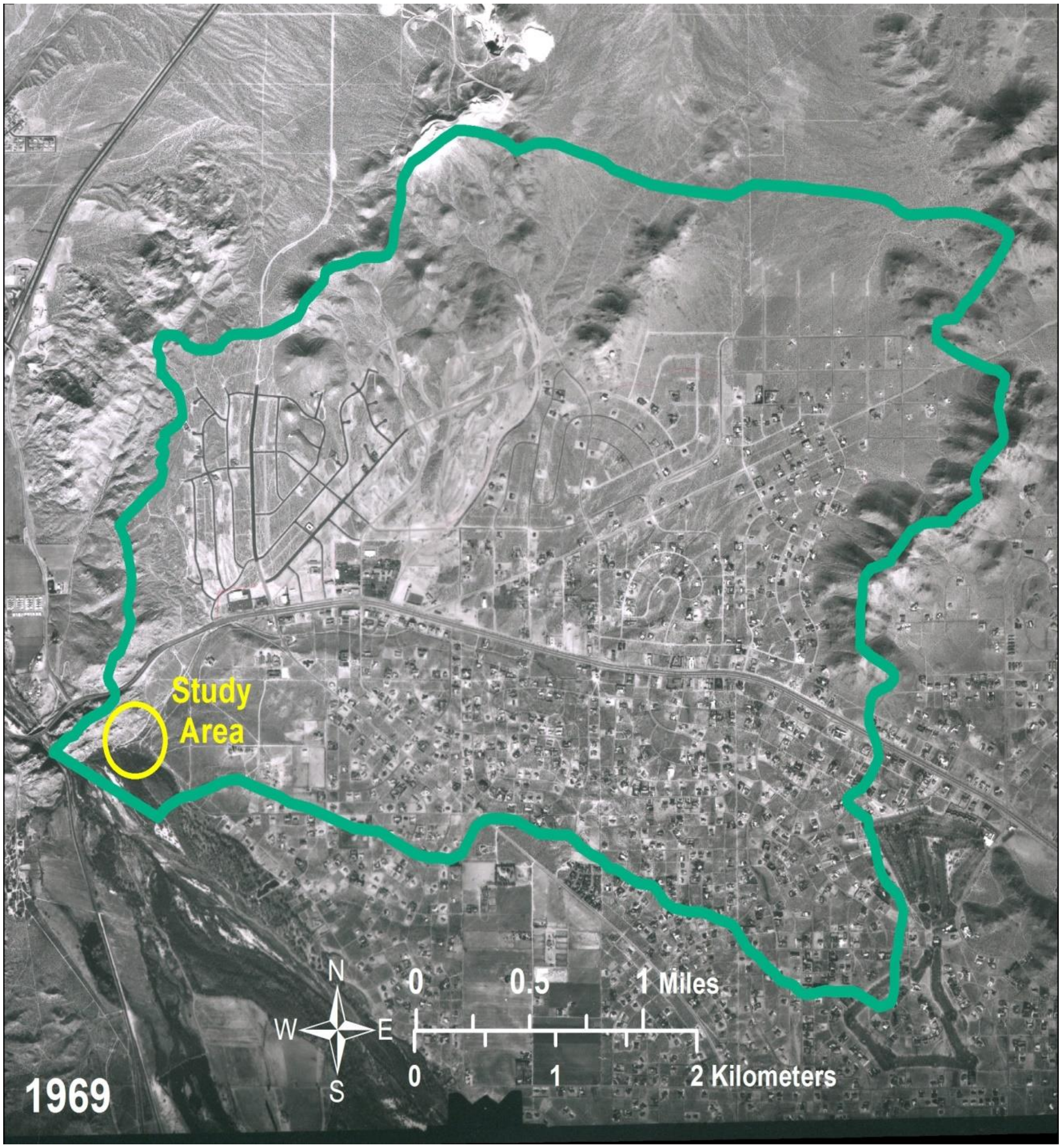

Figure 16. Aerial Photo Dated 1969.
The green line shows the Desert Knolls Wash drainage basin boundary (Mojave Water Agency, 2013).

Figure 17. Aerial Photo Dated 2000.
The green line shows the Desert Knolls Wash drainage basin boundary (Mojave Water Agency, 2013).

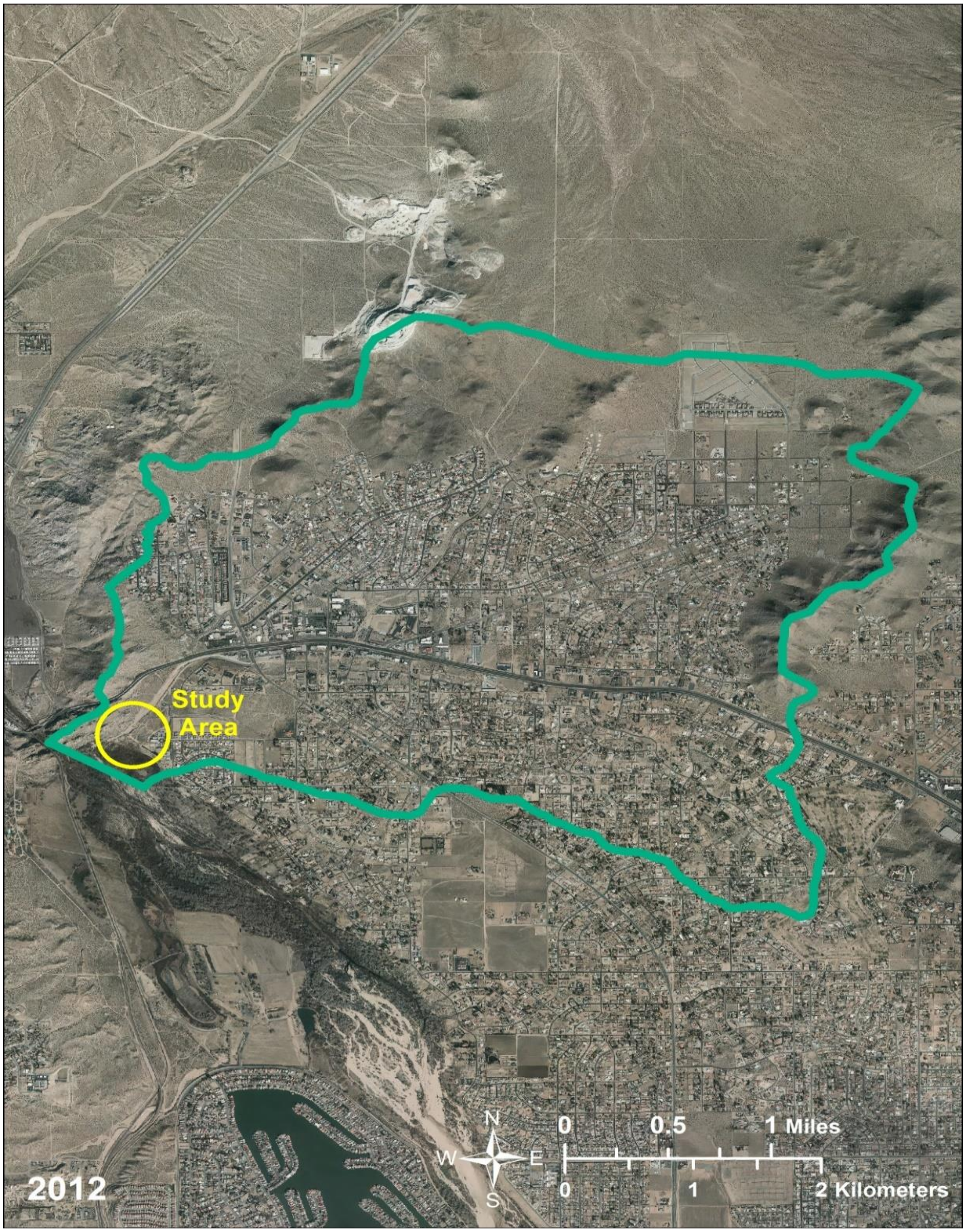

Figure 18. Aerial Photo Dated 2012.
The green line shows the Desert Knolls Wash drainage basin boundary (Mojave Water Agency, 2013).

After printing the maps from the HP Designjet Z2100, they were laid on a Fiskars cutting mat to cut out the portions of paved/constructed areas and roads. All three maps were printed at the exact same scale and on the same heavy base paper. A fluorescent Desktop Magnifying Lamp was utilized to view the built areas through a 3-5/16" lens with a 2x magnification to cut out the built-up and concrete areas on all three maps as shown in Fig. 19.

Figure 19. Photo of Cut Pieces of Paved/Constructed Areas Weighed. Procedure showing the built-up areas being cut and weighed to analyze the rate of urbanization in the Desert Knolls Wash drainage basin.

The built-up and concrete areas on the map were then cut and weighed on an "Acculab" digital scale with a capacity of 4000gm at intervals of 1 gm. Each of the three maps weighed 31.00 gm. The urbanized areas cut out of the 1969 map weighed 6 gm. The weighed area was then divided with the weight of the whole project area arriving at 19% urbanization as shown in Table 8.

Table 8. Urbanization in the Desert Knolls Wash Drainage Basin, 1969-2012

Year	Weight of the mapped drainage basin area in grams	Weight of the urbanized map area in grams	Calculation	Urbanization
1969	31.00	6.00	6÷31	19%
2000	31.00	10.00	10÷31	32%
2012	31.00	12.00	12÷31	39%

The same procedure was repeated for the next two maps. The 1969-2000 intervals showed an increase in urbanization from19% to 32%. The urbanization increased to 39% during the next 12 years. A thorough search for recorded flood data for this basin was made, but not found.

CHAPTER FIVE

MAJOR FINDINGS AND DISCUSSION OF RESULTS

To determine the impacts on the DKW, three channel cross-section surveys were conducted between May 2012 and November 2014 (see Fig. 20).

Figure 20. Photo of Transect B.
Surveying the transect at the south-western end of the Desert Knolls Wash

The two transects were measured on November 02, 2012 (see Figs. 21 and 22). They were then remeasured again 10 days later on November 12, 2012 (see Figs. 23 and 24) because there was light rain on November 08, 2012 between 11:35 a.m. and 4:55 p.m. On November 09, 2012 there was a second light rain again between 5:35 p.m. and 6:15 p.m. This was followed by light snow on November 12, 2012 at 6:35 a.m. The results did not reveal significant channel changes (Weather archives for Apple Valley, CA 2012).

In late 2014, after having waited for almost two years for a significant precipitation event, it was time to conclude study of the DKW (see Figs. 25 and 26). On November 8, 2014, the final survey was conducted of the DKW transects. The survey chaining pins for both transects were still present where they had been installed 30 months earlier, setting the preconditions for an accurate remeasure of any changes that may have occurred. The same surveying methods were used. Evidence of a local urbanization change was present in the form of a new raised sewer pipe and a small security building at the end of the wash.

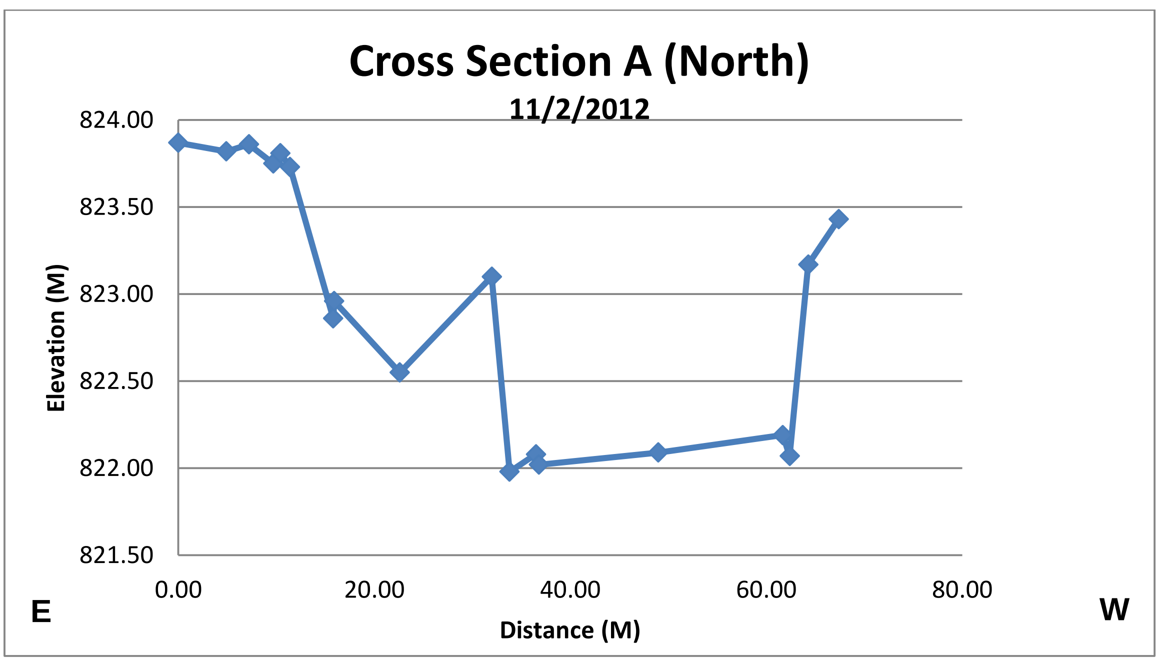

Figure 21. Graph Showing Cross Section A (North) 11/01/2012.
Vertical exaggeration = 10x

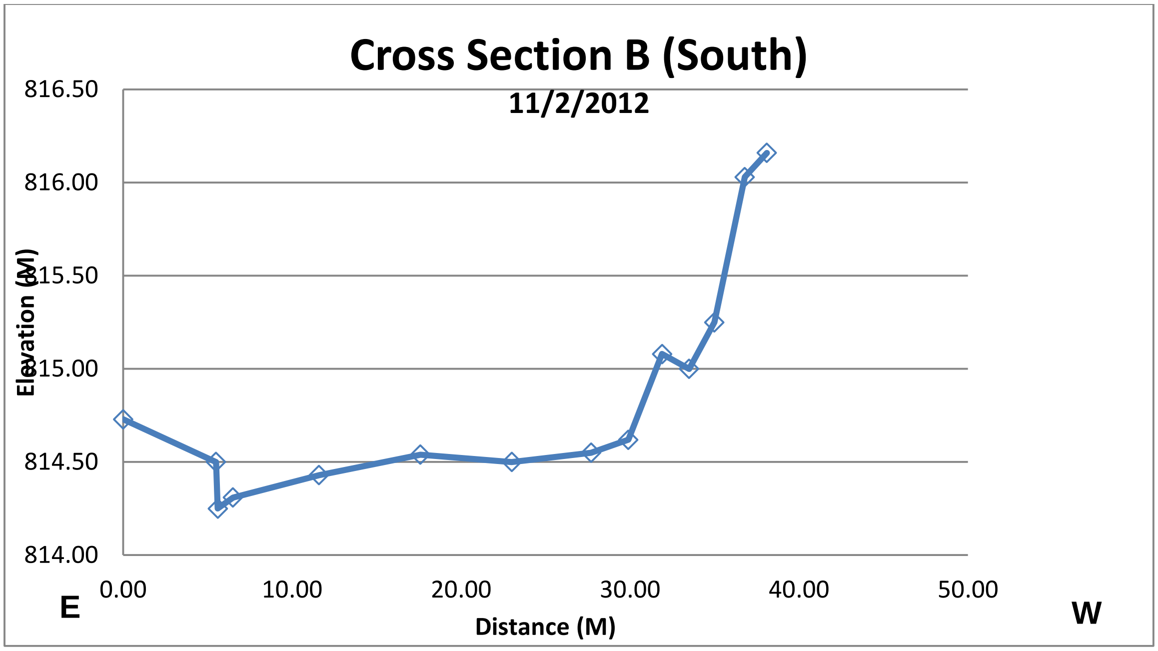

Figure 22. Graph Showing Cross Section B (South) 11/02/2012. Vertical exaggeration = 10x

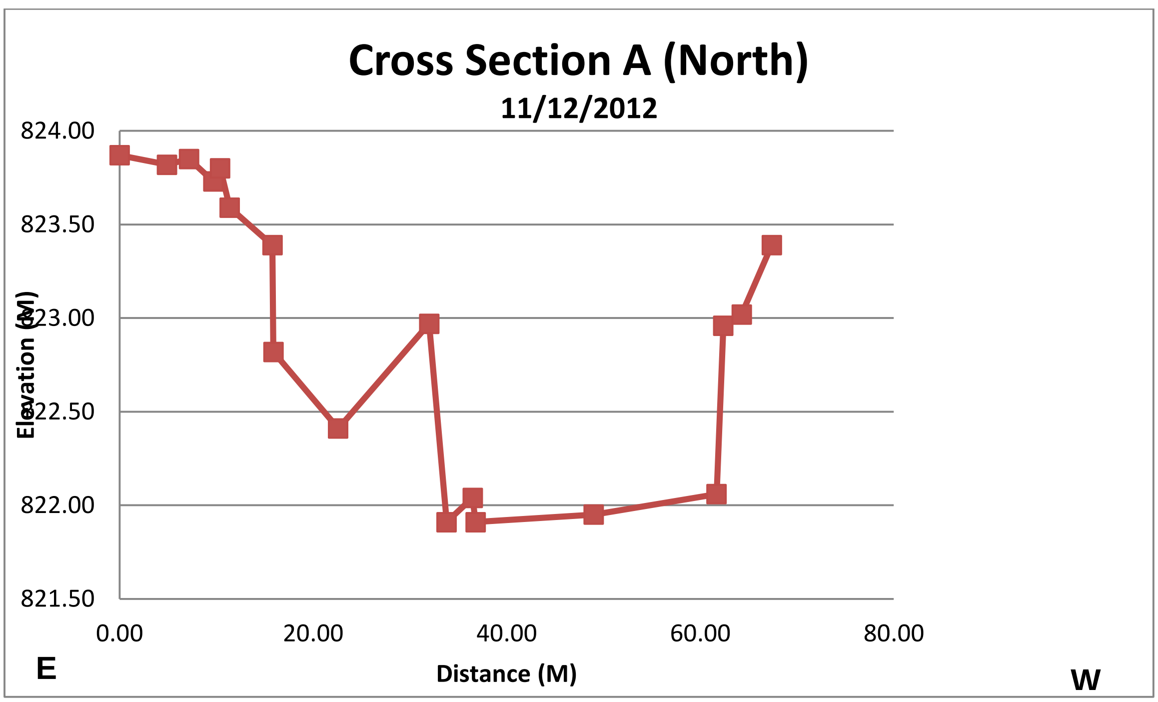

Figure 23. Graph Showing Cross Section A (North) 11/12/2012. Vertical exaggeration = 10x

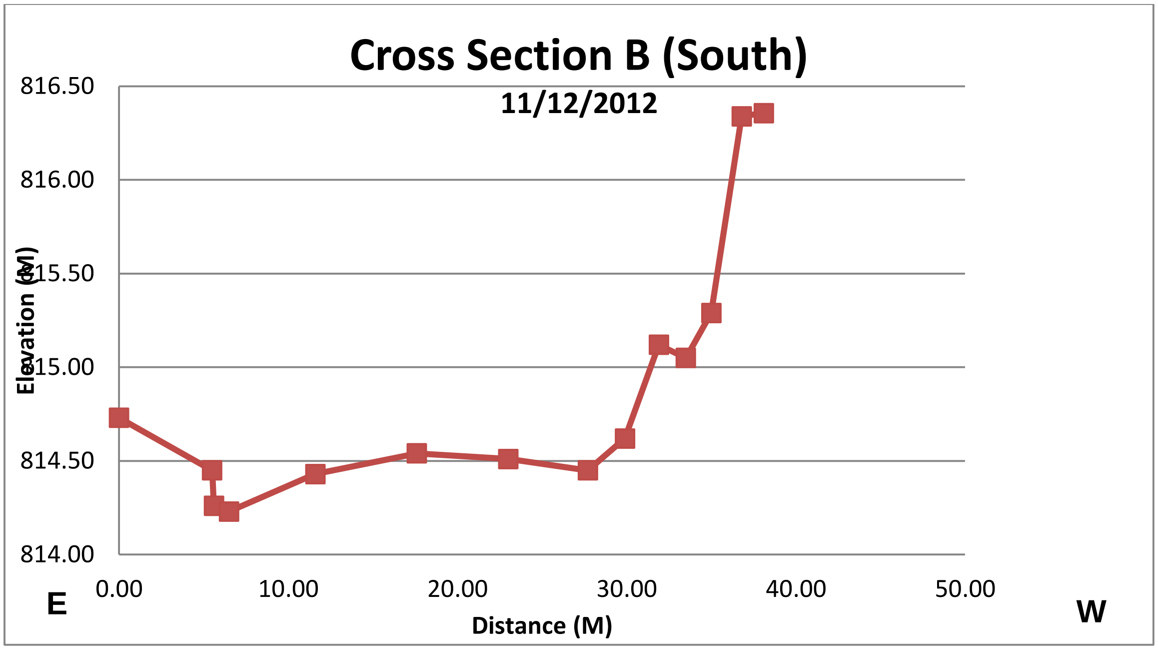

Figure 24 Graph Showing Cross Section B (South) 11/12/2012.
Vertical exaggeration = 10x

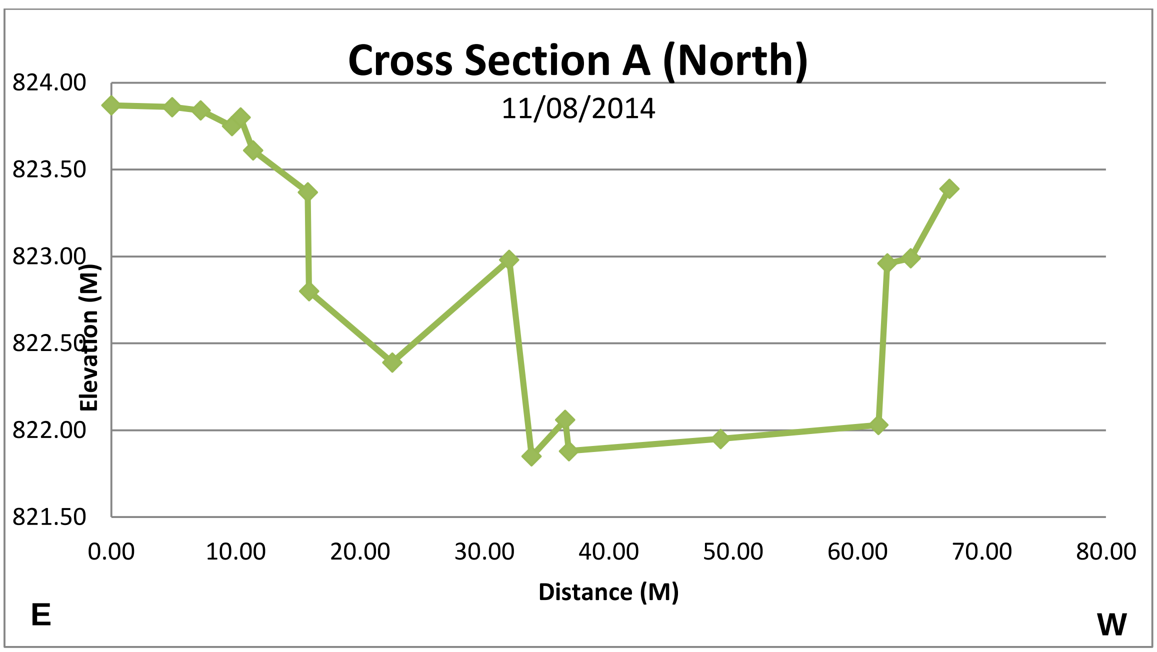

Figure 25. Graph Showing Cross Section A (North) 11/08/2014.
Vertical exaggeration = 10x

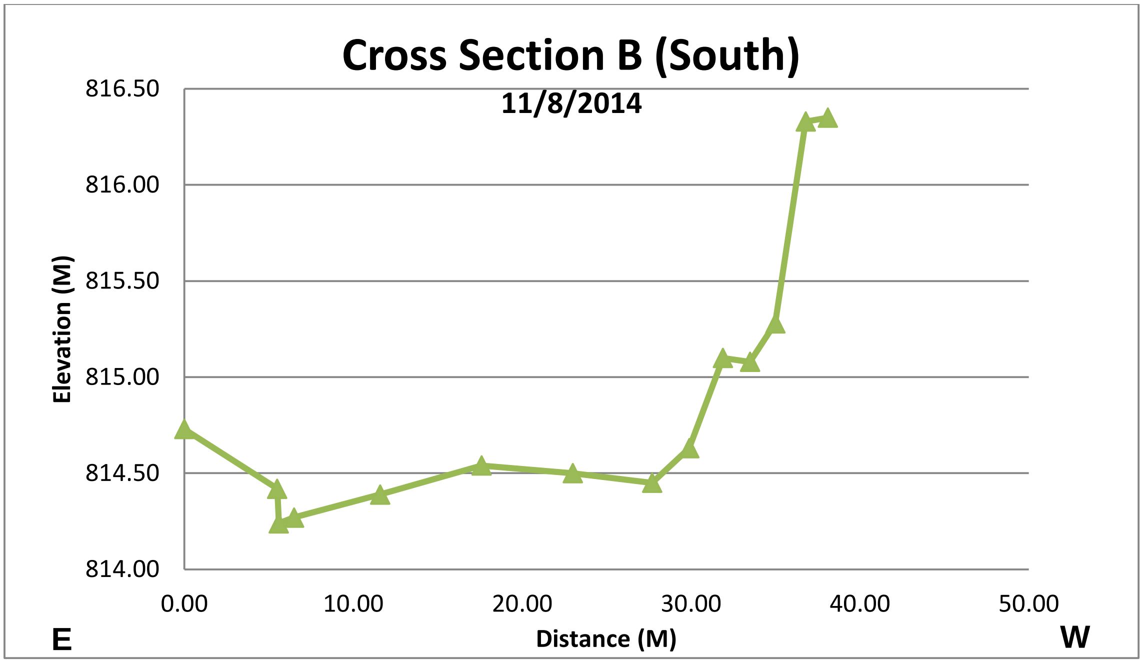

Figure 26 Graph Showing Cross Section B (South) 11/08/2014.
Vertical exaggeration = 10x

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

This project has been conducted over the length of two and a half years. Normally, two and a half years should be sufficient time for measurable changes to occur in a Mojave Desert wash. Manmade changes in the study area have occurred. By the time the final transect measurements were collected in November 2014, a new sewer pipe was being constructed along a dirt road on an elevated bank along the south side of the DKW. The pipe was resting on raised supports above the ground, and a portable building had been erected for security. These additions are east of the cottonwood tree and along one side of the channel profile transect lines. With this many obvious manmade changes to the landscape it is a fair assumption that there would be measurable changes in the geomorphology of the DKW.

However, this was not the case. The specific channel reach of the DKW being monitored did not experience significant and measurable changes since data were first collected in November 2012 (see Figs. 27 and 28). There may have been small local changes, but these differences are not large enough to be considered significant. As a result, I am unable to make conclusions about activity in the DKW.

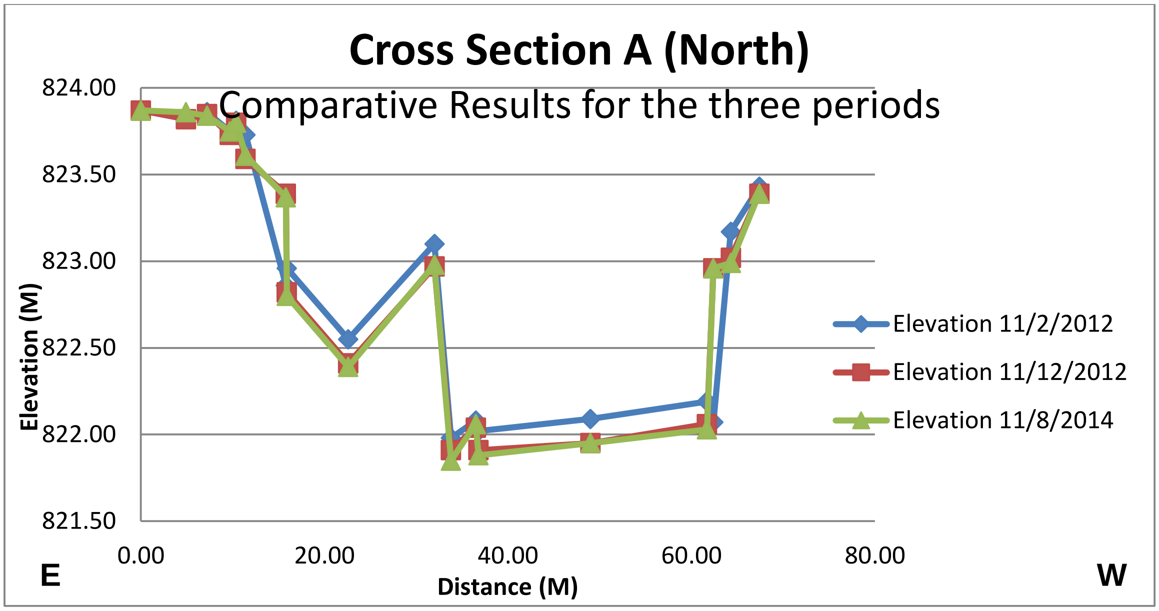

Figure 27. Comparative Graphs for Section A (North)
Three graphs were plotted on transect A to show comparative results for the three periods. Vertical exaggeration = 10x

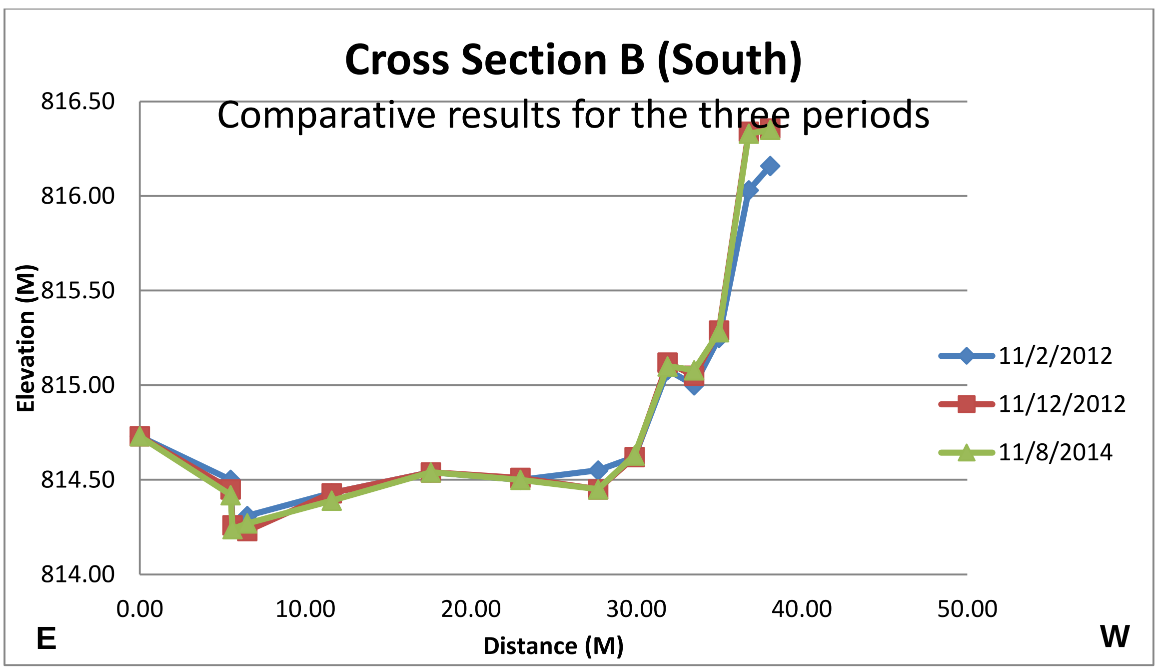

Figure 28. Comparative Graphs for Section B (South).
Three graphs were plotted on transect B to show comparative results for the three periods. Vertical exaggeration = 10x

Analysis

One reason the DKW did not significantly change is because there were no significant large precipitation events or floods during the duration of the study. In fact, Apple Valley, the High Desert, and California at large have been experiencing a drought. This drought has persisted throughout the study. The National Oceanic and Atmospheric Administration (2014) illustrated the progression of drought conditions in California from 2012 to 2014 (see Figs. 29, 30, and 31). The progression goes from moderate drought to extreme drought. Without rain, desert channels do not change significantly.

Local rainfall for the past two and half years was significantly below average. Runoff from a heavy precipitation event was expected to have picked up speed as it rushed towards the unarmored part of the DKW causing the ground to be degraded and deposition of sand to occur downstream. However, since there were no significant heavy rainfall events during the period, no significant changes occurred that could be documented.

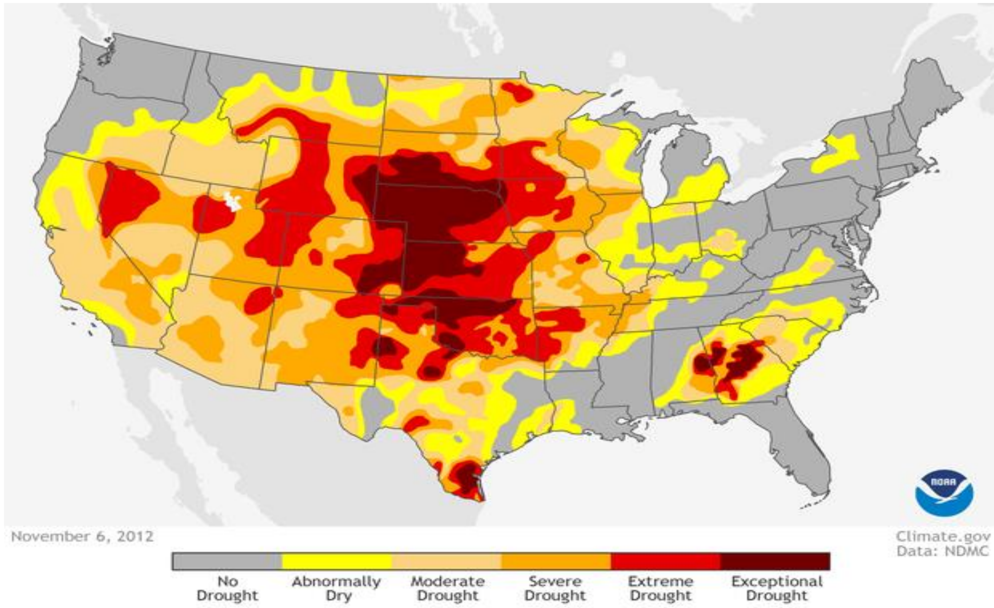

Figure 29. Map of Drought Conditions during 2012 in California (NOAA, 2012).

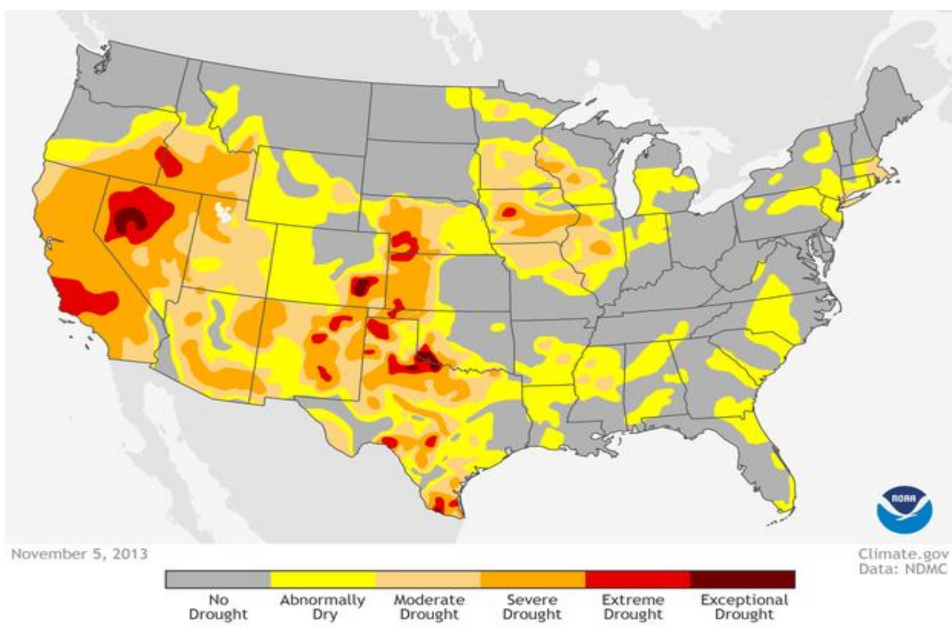

Figure 30. Map of Drought Conditions during 2013 in California (NOAA, 2013). Notice the progression of severity of drought.

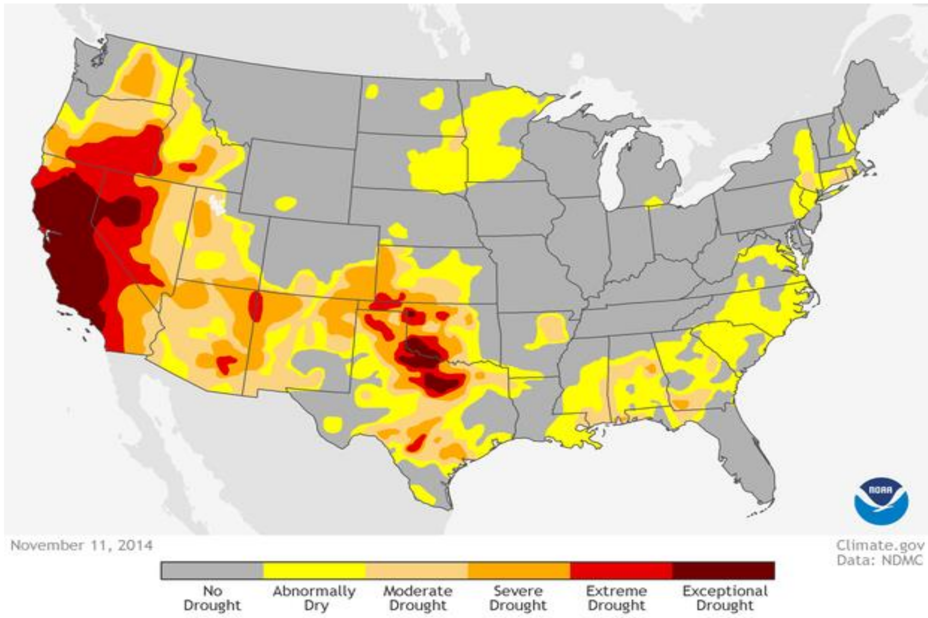

Figure 31. Map of Drought Conditions during 2014 in California (NOAA). Notice the increased progression of severity of drought.in California.

To further investigate the scope of the drought present, the US Climate Data, Weather Archives for Apple Valley, was accessed. In the year 2012 the annual precipitation in Apple Valley was 4.15 inches (Weather Archives for Apple Valley, CA, 2012). In year 2013 the annual precipitation was 1.82 inches, followed by an annual precipitation of 1.80 inches in 2014.

The persistent drought for two and half years present in California, and specifically in the Apple Valley region of the High Desert, has prevented recording dynamic changes from occurring in the channel. Even though urbanization in the drainage basin increased from 1969 to 2014, and large floods should have caused accelerating degradation downstream from the cemented channel, and perhaps increased aggradation near where the DKW joins the

Mojave River, none of this has happened. So no conclusions can be made at this time. However, if measures are not taken to prevent erosion, degradation or widening of the channel could affect the athletic field and cause damage.

The baseline measurements reported in this study might be used by students in the future to study the impacts of urbanization on a desert wash such as DKW. One result of this project may be to persuade future city planners to consider finishing engineering projects along such washes before planning urban growth. The goal of this project was to document the magnitude and timing of the ongoing channel changes, as well as predict what will likely happen over the next two decades if measures are not taken to stabilize the channel permanently.

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