Seepage Losses for the Rio Grande Project

(Franklin Canal Case Study)

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Executive Summary

This document presents preliminary findings on seepage losses estimated by the ponding tests and the current meter flow measurements along Franklin Canal. It includes two parts: the first part covers the seepage losses of the total 5.29-mile reach of the Franklin Canal between the Franklin Canal Heading and the Ascarate Wasteway (divided by Fox Plaza for two time periods, one in January and the other one in November) based on ponding tests; and the second part of the report illustrates the seepage losses estimated for the same reach of Franklin Canal based on current meter flow measurements.

Three ponding tests were conducted at the Franklin Canal between the Heading and Fox Plaza in January 2002 and two additional ponding tests were conducted at the Franklin Canal between the Fox Plaza and the Ascarate Wasteway in November 2002. The test results showed that water losses ranged from 0.107 to 0.341 cubic ft per day per square feet of the wetted area (cub. ft/sq. ft/day). The total seepage losses for the first 5.29-mile reach of the Franklin Canal were estimated up to 1800 ac-ft, which include 1,181 ac-ft (or 362.3 ac-ft per mile) from Heading to Fox Plaza and 620 ac-ft (or 305.4 ac-ft per mile) from Fox Plaza to Ascarate Wasteway for the irrigation season. Both ponding tests indicated that seepage losses varied from one location to another, which might be attributed to the difference in the soil properties and the hydraulic conditions. The results also indicated the possible seasonal variation up to 50% increase from the beginning of the irrigation season to the end of the season.

The results of the current meter flow measurements showed higher seepage losses than those from the ponding tests. The inflow/outflow measurements showed that the unit seepage losses ranged from 0.76 to 1.71 cubic feet per square feet of wetted area per day (cub. ft/sq. ft/day) for the 5.29-mile reach of Franklin Canal. It was estimated that the seepage losses for this reach of Franklin Canal ranged from 4, 620 to 10,384 ac-ft (or 883.5 to 1985.5 ac-ft/mile) for the irrigation season. In general, seepage losses estimate from the current meter flow measurement are larger than those from the ponding tests.

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Introduction

The El Paso Del Norte Region, composed of the cities of El Paso, Texas; Las Cruces, New Mexico in the United States; and Ciudad Juarez, Chihuahua, in Mexico, is facing a severe drought and as a result, a significant reduction in surface water allotments is forecasted for the

upcoming irrigation season. Water conservation strategies have become even more urgent. El Paso County Water Improvement District No. 1 (EPCWID No.1) and Elephant Butte Irrigation District (EBID) operate and maintain over 500 miles canals and laterals, and deliver approximately 870,000 ac-feet of the Rio Grande Project water in a full allotment year to the irrigated land for agricultural production and to municipal water utilities for urban water supply in Texas and New Mexico. Most of the Rio Grande Project canals and laterals are not lined. Previous seepage losses studies conducted by the U.S. Geological Survey (USGS), the U.S. Bureau of Reclamation and the Irrigation Districts revealed significant amounts of seepage losses in the Franklin Canal (Blair, 2001). In 1972, the USGS estimated seepage losses in the Franklin Canal at 0.3 cub. ft/s per mile (Slade, Bentley, and Michaud, 2002). In 1984, the estimate of average seepage losses conducted by the U.S. Bureau of Reclamation (USBR) was at 0.82 cub. ft/s per mile (White, Baker and Sperka, 1997). In 1992, the USGS conducted additional seepage losses study about the same section of the Franklin canal in which the USBR conducted its measurements in 1984, and estimated seepage losses at 4 cub. ft/s per mile (White, Baker and Sperka, 1997).

The Franklin Canal, constructed in 1890, currently flows for 28.25 miles through many of the City's low to moderate-income neighborhoods, and irrigates thousands of acres along its way. Recent studies indicated that besides improvement of delivery efficiency and water savings, there are other benefits by lining canals such as less maintenance, healthy environment. (Blair, 2001; Brown, 2000). However, it is necessary to determine the total water saved by lining canal and weigh the benefits against costs because lining of the canals is very expensive.

To better understand the seepage losses and estimate potential for water savings, scientist and engineers from Texas A&M University and New Mexico State University conducted ponding tests and flow measurements in the selected portions of regional canals and laterals. This project was supported by Rio Grande Basin Initiative of USDA CSREES. It was also supported in part by Texas Water Resources Institute, Texas Agricultural Experiment Station, the U.S. Bureau of Reclamation and El Paso County Water Improvement District. Five ponding tests were conducted along the first 5.29-mile reach of the Franklin Canal in 2002. Current meter flow measurements were conducted during August, September and October of year 2002.

Methods for Determination of Seepage Losses

(1) Ponding Tests

Ponding test measures how fast water seeps from the canal into the ground through the canal beds and banks. Berms were built with compacted soil at pre-selected sites. Two 24-inch pipes were placed at approximately three feet above the canal floor on each berm to allow downstream flow to other ponding sites, and to prevent flooding that could have been caused by an excessive amount of water. Staff gauges were installed under the bridges upstream from the berms to measure water level. After the berms were built, water was fed into the first ponding site at a rate of 5 to 10 cubic feet per second (cfs). Water for the downstream ponding sites was fed through the installed 24-inch pipes on the berm. The canal beds and side berms were saturated for over 48 hours before ponding tests were conducted. Once water inflow and outflow ceased at each site, measurement of water level readings, water temperature, air temperature, and relative

humidity were initiated. Air temperature and relative humidity were measured with a digital hand-held meter and cross-referenced and checked with the national weather station at the El Paso International Airport. Water temperature was measured with a standard thermometer. Water level, water temperature, air temperature and relative humidity were measured and logged every one to four hours at each ponding site during each day.

(2) Current Meter Flow Measurements

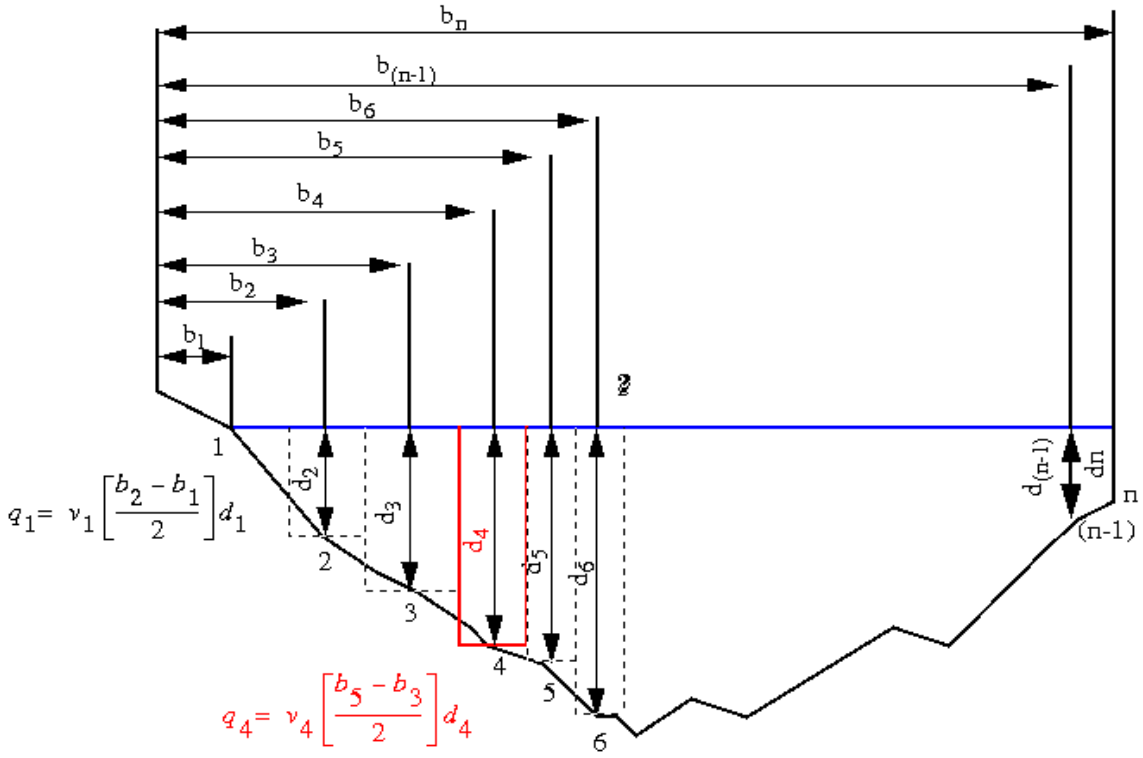
Current meter flow measurement is an "in-flow/out-flow" measurement method, which consists of placing current meters along the cross-section of a canal to measure the speed at which water flows. By multiplying the velocity of water by the cross-sectional area of the canal, discharge can be calculated (Fig. 1). The sum of the incremental discharges yields the total discharge of the stream.

The Price AA meter was used to measure the velocity of the flowing water. In all measurements the revolutions of the rotor was counted during a measurement interval of time using a digital meter reader. Once the counts are established the velocity can be determined using a table provided with the current meter. Also, the velocity in cubic feet per second (cfs) can be calculated using the equation:

$$V=2.2048\ R + 0.0178$$ (R denotes revolutions per second)

There are two wading methods that could be used in measuring the flow in a canal: the one point method and the two-point method. The one point method is used for water depths less than 2.5ft. When using this method, the current meter is adjusted to a level of 0.6 (60%) of the water depth from the top. When using the two-point method the current is measured at two vertical points: 0.2 (20%) and 0.8 (80%) depths respectively from the top of the water surface. The flows at these two levels are then averaged to get a single measurement. Current should generally be larger at the 0.2 depths but should not be larger than twice the current at the 0.8 depths. If the current at the 0.2 depths is not larger than the 0.8 depths or if it is twice as great as the 0.8 depths, then an additional reading should be taken at the 0.6 depths. These 0.6 depths should be averaged with the 0.8 and 0.2 mean.

When conducting seepage studies for flows that are not in steady state, it is important that the time interval between the measurements of the two cross sections is appropriate. Once the current flow measurement is completed at the upstream section, the average velocity should be calculated. The distance from the upstream site to the downstream site divided by the average velocity is the time gap between the upstream and downstream measurements.



Explanation

1,2,3 .....n --Observation verticals

$b_1, b_2, b_3, ...b_n$ --Distance from initial point to observation vertical

$d_1,d_2,d_3,.....d_n$ --Depth of water at observation vertical

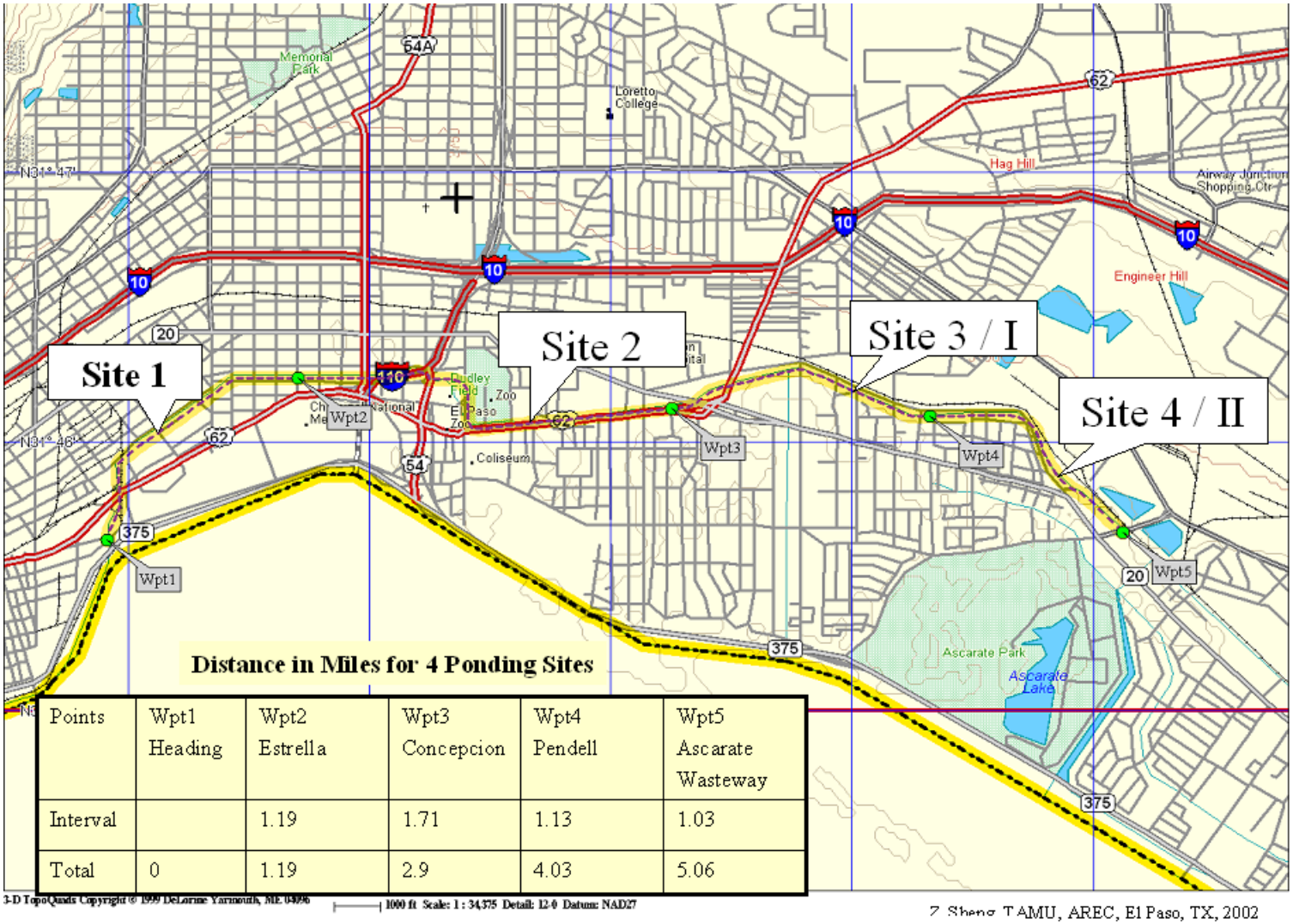
Dashed lines --Boundaries of subsections

Figure 1—Sketch of discharge computing method
(From Nolan and Shields, 2000)

Field Measurements Data

(1) Ponding Tests

From January 25 through January 29, 2002, three ponding tests were conducted on the Franklin Canal to determine water losses due to seepage. El Paso County Water Improvement District No. 1 (EPCWID No. 1) staff constructed berms (earth dams) to form three ponding sites along the Franklin Canal, and installed staff gages to record water level readings. One berm was constructed near the Estrella Street Bridge, another one near the intersection of Paisano and Alameda, and a third one near the Pendell Street Bridge (See Map 1).



Points	Wpt1 Heading	Wpt2 Estrella	Wpt3 Concepcion	Wpt4 Pendell	Wpt5 Ascarate Wasteway
Interval		1.19	1.71	1.13	1.03
Total	0	1.19	2.9	4.03	5.06

MAP 1 Locations of Ponding Test Sites

Picture 1: Staff gage measuring water level

Ponding test for site one (Site 1), near the La Estrella Street Bridge, was started on January 25, 2002. Water level recorded on the staff gage readings (Picture 1) ranged from 0.915 ft on the first day to 0.19 ft on the fourth day. There was a total water level change of 0.725 ft due to seepage and evaporation at this observation site. The seepage rate was fairly constant throughout the testing period except for the last two days in which the seepage rate dropped slightly (Figure 1), possibly due to lower head driving force. Water temperature was also fairly constant. It ranged from 5°C to 10°C, but air temperature varied considerably from 13°C to 30°C. Relative humidity also varied from 17% to 35%.

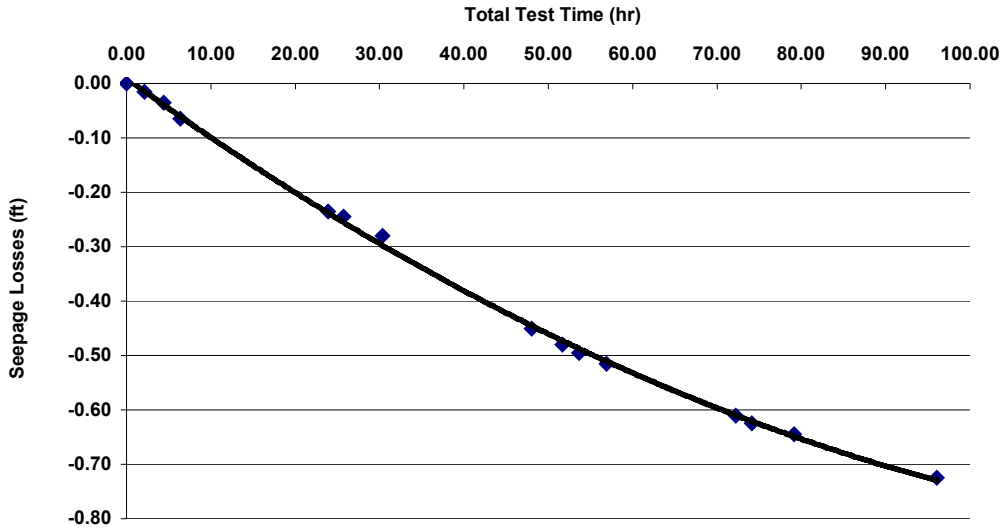


Figure 1. Seepage Losses (including ET) at Site 1

Ponding site two (Site 2) located on Concepcion Street near the Paisano and Alameda intersection (Picture 2) was started on January 25, 2002. The water level at this site dropped 1.095 ft, from 1.19 ft to 0.095 ft during the four-day period. Seepage rate was constant throughout the day (Figure 2). For this ponding site, water temperature did not change considerably. The temperature was as low as 7°C and the high was 12°C. On the other hand, the air temperature varied somewhat from 12°C to 27°C. Relative humidity ranged from 18% to 43% during the four-day test period.

Ponding site three (Site 3), located near Pendell Street (Picture 3) below Fox Plaza, was started on January 26, 2002. The water level dropped 0.365 ft in the third day at a constant rate (Figure 3). Measurements were taken only during the day. This pond site had the smallest variance in

rate and also the smallest water level drop. Water and air temperature ranged from 6°C to 10°C and 7°C to 27°C respectively. Relative humidity at this site also ranged from 17% to 37%.

Picture 2: Ponding test site 2

Picture 3: Ponding test site 3

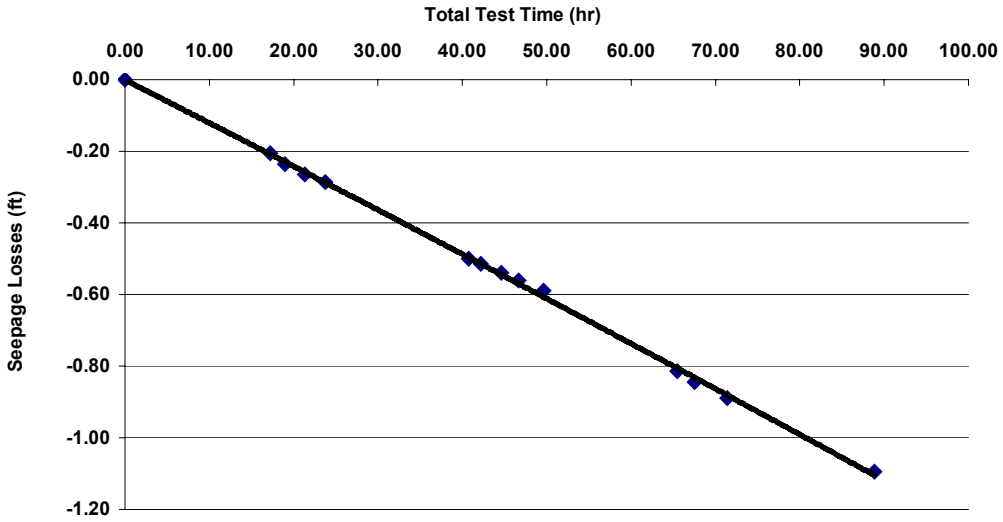


Figure 2. Seepage Losses (including ET) at Site 2

From November 8 through 13, 2002, ponding tests were conducted on another two ponding sites along the Franklin Canal (Map 1). For later results comparison purpose, ponding site one (Site I) was located as the same place as in the January test (near the Pendell Street Bridge). Both sites began on November 8. At Site A, water level recorded on the staff gage ranged from 2.52 ft on the first day to 1.64 ft on the fifth day. There was a total water level change of 0.88 ft due to seepage and evaporation at this observation site. The seepage rate curved slightly with a lower rate for the last three days (Figure 4), possibly due to lower hydraulic head. Water temperature ranged from 8°C to 13°C and air temperature varied considerably from 8.3°C to 27.2°C. Relative humidity also varied from 22.8% to 39.9%.

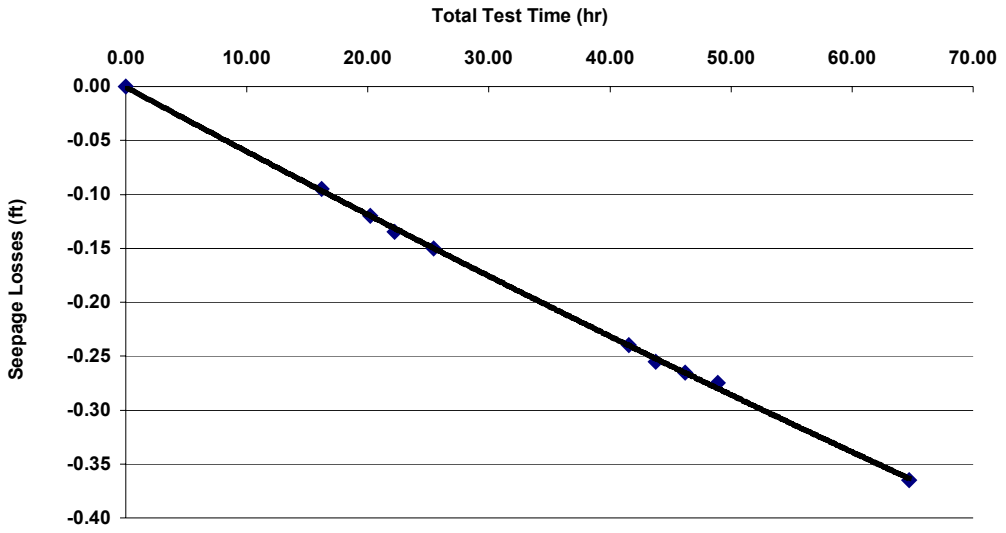


Figure 3. Seepage Losses (including ET) at Site 3

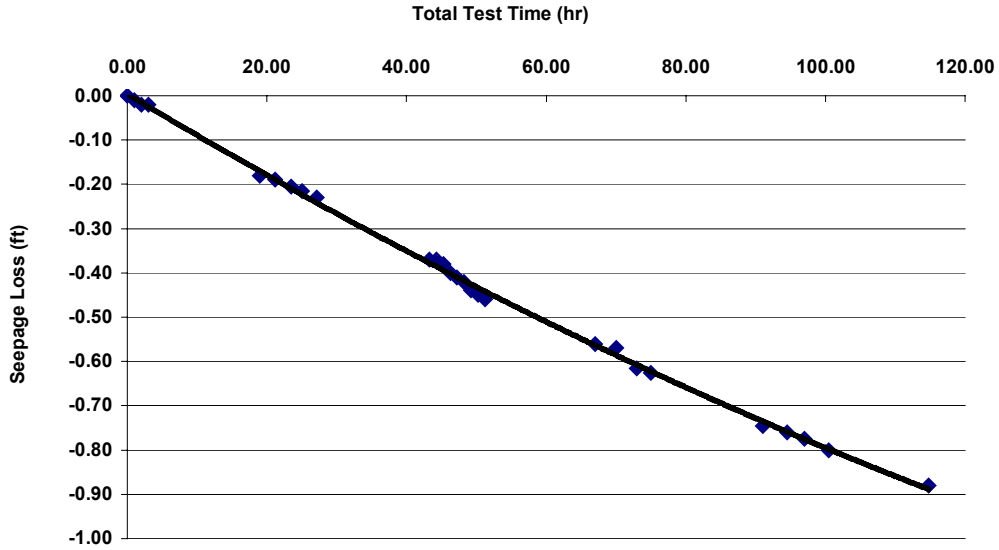


Figure 4. Seepage Losses (including ET) at Site I

The second ponding site (Site II) was located upstream of the Ascarate Wasteway (Picture 4) and the staff gauge was installed beyond the Pasco St. Bridge about a quarter-mile upstream of the berm. The water level at this site dropped 1.21 ft, from 1.27 ft to 0.06 ft during the five-day period. The seepage rate was almost constant (Figure 5). For Site II, water temperature did not change considerably. The water temperature was at a low of 8°C and a high of 14°C. On the other hand, the air temperature varied somewhat from 11.1°C to 27.8°C. Relative humidity ranged from 21.6% to 39% during the five-day test period.

Picture 4—Ponding Site II

Cross-sectional geometry was measured along the Franklin Canal from 500ft upstream of the Pendell St. bridge to 1,000 ft downstream of the Pasco St. bridge. The average values were used as primary geometry parameters for both the January and the November ponding tests analysis. The evaporation rate during January was estimated as 0.007 ft per day and between 0.0026 ft per day and 0.016 ft per day during November based on pan evaporation measurement obtained at the Ysleta station by EPCWID No. 1. The wind speed ranged from 1 to 24 feet per second.

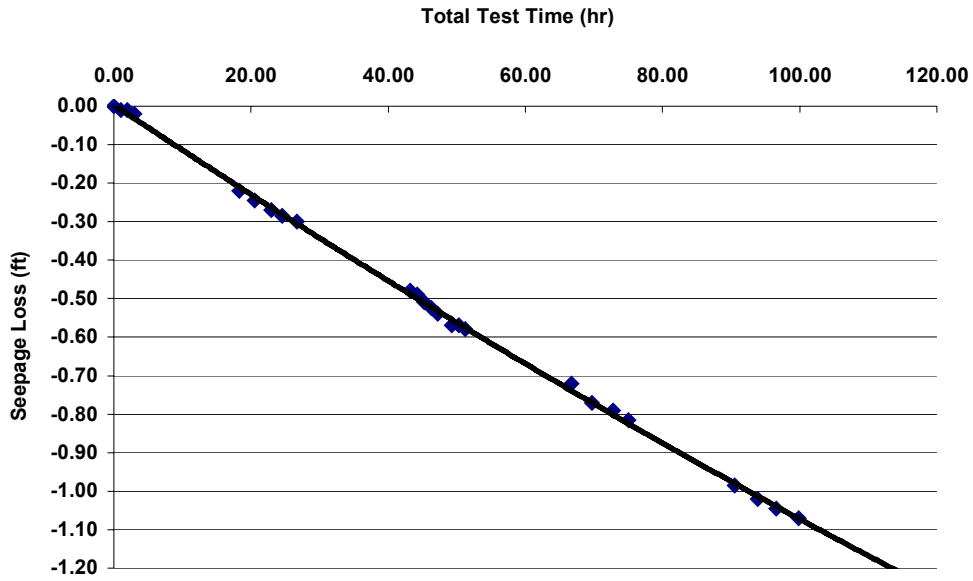


Figure 5. Seepage Losses (including ET) at Site II

(2) Current Meter Flow Measurements

From August to October several measurements were conducted using the current meter method along the Franklin Canal. Measurements taken at Latta St. (upstream inflow) is in the upstream side when compared to the measurements taken at Ascarate Wasteway (downstream outflow) which falls under the downstream site of the canal. The differences in discharge were calculated and also the seepage losses were assessed by determining the water lost in between upper stream and down stream of the canal. One-foot width was used for subsections in our measurement. The total distance from upstream to downstream was estimated as 3.48 miles shown in Map 2. Typical test interval between upstream and downstream cross-sections was 3 hours. Evaporations were included in the total losses. ET values for August, September, and October

were 0.39, 0.24 and 0.18 in/day respectively. Six typical sets of flow measurement were selected as shown in Table 1. The difference between inflow and outflow ranges from 6 to 12.78 cubic feet per second.

Table 1—Current Meter Flow Measurement Data

Date	Location	Flow (ft^3/sec)	Seepage Loss (ft^3/sec)	Water Depth (ft)	Water Top Width (ft)	Bottom Width (ft)	Wetted Perimeter (ft)
8/1/02	FC/Latta	209.1					
	FC/Ascarate	202.9	6.2	3.3	35.95	27.83	38.29
8/8/02	FC/Latta	210.49					
	FC/Ascarate	202.66	7.83	3.3	35.95	27.83	38.29
9/18/02	FC/Latta	141.41					
	FC/Ascarate	128.63	12.78	2.3	33.49	27.83	35.12
9/19/02	FC/Latta	174.83					
	FC/Ascarate	163.57	11.26	3.05	35.33	27.83	37.50
10/2/02	FC/Latta	109					
	FC/Ascarate	98.41	10.59	1.93	32.58	27.83	33.95
10/4/02	FC/Latta	106					
	FC/Ascarate	100	6	1.92	32.55	27.83	33.92

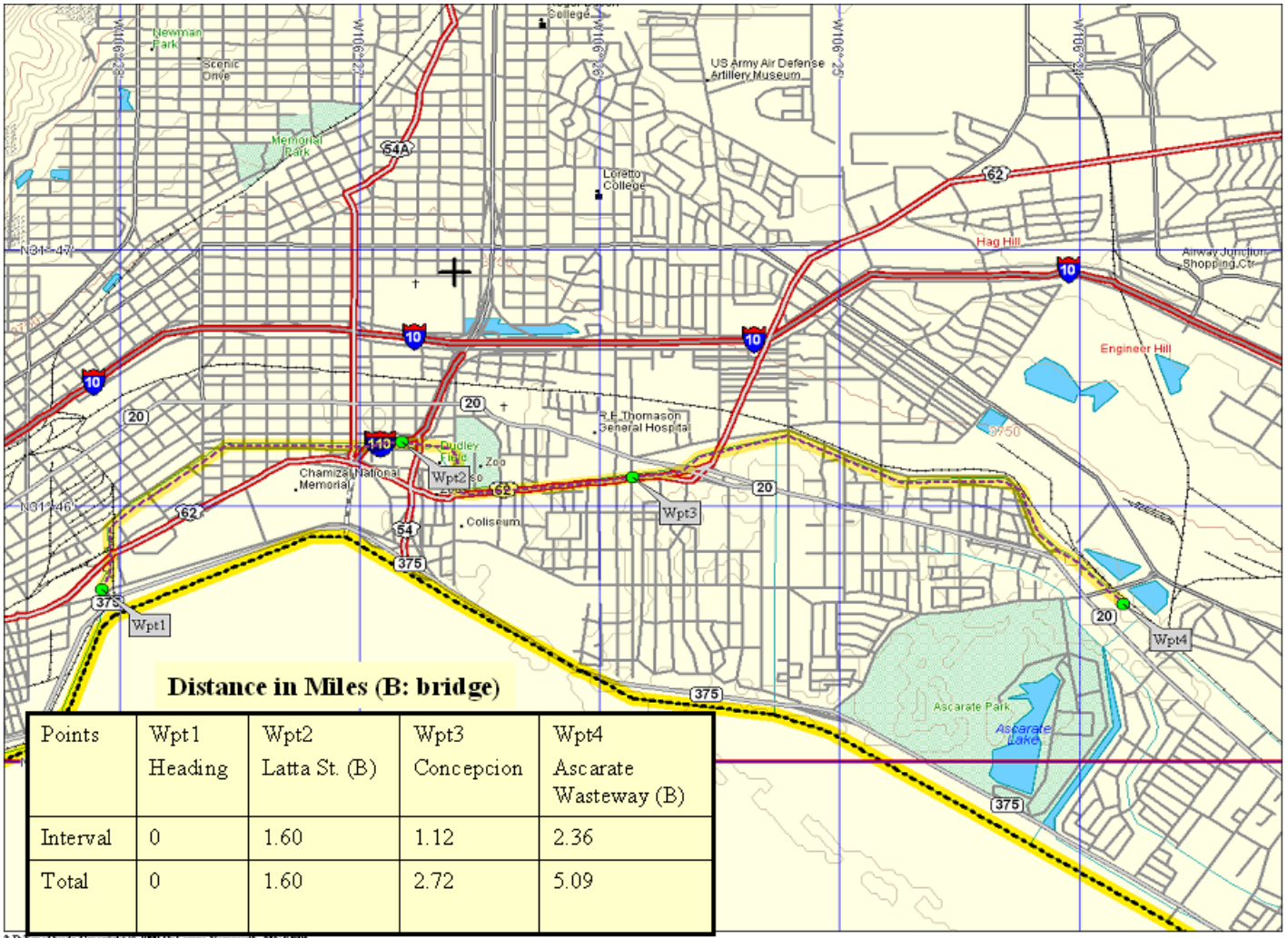
Results of Analysis

(1) Unit seepage losses

- ***Ponding Tests***

The water level change rates were found by adding linear trend lines to the measured data series (Figures 1 to 5). Maximum and minimum water-level change rates are listed in column 2 of Table 2. Based on water level changing measurement and geometry of canal cross-sections as listed in Table 2, seepage losses per unit-wetted area were calculated as shown in column 3 of Table 3. During January, seepage losses at Site 1 ranged from 0.108 to 0.213 cubic feet per square feet of wetted area per day (cub. ft/sq. ft/day). Seepage losses at Site 2 ranged from 0.287 to 0.342 cub. ft/sq. ft/day. Seepage losses for Site 3 were from 0.118 to 0.137 cub. ft/sq. ft/day. During November, seepage losses at Site I ranged from 0.164 to 0.203 cub. ft/sq. ft/day. Seepage losses at Site II were from 0.246 to 0.263 cub. ft/sq. ft/day.

To estimate unit seepage losses for the irrigation season, the following parameters were used: For sites 1 and 2, a water top width of 34 ft, the bottom width of the canal of 26 ft,



Points	Wpt1 Heading	Wpt2 Latta St. (B)	Wpt3 Concepcion	Wpt4 Ascarate Wasteway (B)
Interval	0	1.60	1.12	2.36
Total	0	1.60	2.72	5.09

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MAP 2 Locations of Current Meter Flow Measurements

Table 2—Ponding Test Measurements

Ponding Site	Water Level Change Rate (ft/day)		Water Top Width (ft)	Top Canal Width (ft)	Bottom Canal Width (ft)	Water Depth (ft)	Slope	Wetted Perimeter (ft)
Site 1 - Jan	Max	0.22	32.10	39.87	27.78	1.60	1.35	33.16
	Min	0.11	30.75	39.87	27.78	1.10	1.35	31.48
Site 2 - Jan	Max	0.35	26.50	37.9	23.98	0.96	1.32	27.14
	Min	0.29	24.84	37.9	23.98	0.33	1.32	25.06
Site 3- Jan	Max	0.14	33.77	41.53	29.18	1.90	1.21	34.55
	Min	0.12	31.96	41.53	29.18	1.20	1.21	32.43
Site I – Nov	Max	0.21	33.17	41.53	29.18	1.65	1.21	34.36
	Min	0.17	32.93	41.53	29.18	1.55	1.21	34.05
Site II- Nov	Max	0.27	32.01	42.21	29.14	1.19	1.21	32.86
	Min	0.25	31.02	42.21	29.14	0.78	1.21	31.57

a water depth of 3.0 ft, the wetted perimeter of 36 ft and a slope of 1.34:1; and for site 3 and Sites I and II (Downstream of Fox Plaza), a water top width 37.3 ft, a bottom width of the canal of 30 ft, a water depth of 3.0 ft, the wetted perimeter of 39.4 ft and a slope of 1.21:1. Early stage seepage loss rates were used to estimate unit seepage losses for the irrigation season because of hydraulic condition similarities between the high water level ponding and irrigation flow. The estimated seepage losses range from 0.236 to 0.752 cfs/mile (0.469 to 1.491 ac-ft/mile/day) as shown in Table 3. It should be noted that all the water losses analyses include water losses due to evaporation. The evaporation rate during the four-day test period was estimated at 0.007 ft per day during January and from 0.0026 to 0.016 during November based on pan evaporation measurement obtained at the Ysleta station by EPCWID No. 1.

- ***Current Meter Flow Measurements***

Based on inflow/outflow measurement and the geometry of the canal cross-sections as listed in Table 1, seepage losses per unit-wetted area were calculated as shown in column 2 of Table 4. The unit seepage losses measured ranged from 0.76 to 1.71 cub. ft/sq. ft/day. The measured unit seepage losses were used to estimate the unit seepage losses for the irrigation season. The following design geometry values were used to calculate the estimated seepage losses: For Site 1 and Site 2, a Water Top of Width 34 ft, a Water depth of 3 ft, a Bottom Width of 26 ft, a Wetted Perimeter of 36 ft and a Slope of 1.34:1 was used; For Site 3, Site I and Site II, a water top width of 37.3 ft, a water depth of 3 ft, a bottom width of the canal of 30 ft, the wetted perimeter 39.4 ft and a slope of 1.21:1 was used. The estimated unit seepage losses ranged from 1.83 to 4.12 cfs/mile (3.64 to 8.17 ac-ft/mile/day). It should be noted that the evaporation rate was taken into account for all water losses estimates.

(2) Total seepage losses for the irrigation season

- ***Results from the Ponding Tests***

The total seepage losses for the irrigation season were estimated by multiplying the estimated unit seepage losses by 243 days as shown in the last column of Table 4. They ranged from 113.94 to 362.33 ac-ft/mile. The total seepage loss for the 3.26-mile reach of the Franklin Canal was estimated up to 1,181 ac-ft (or 362.33 ac-ft per mile) for the irrigation season (Table 3). Please note only site 1 and 2 will be used to estimate seepage for the 3.26-mile reach of the Franklin Canal. Site 3 is below Fox Plaza and was used to compare results with Site I as for same location, different season. The total seepage loss for the second 2.03-mile reach of the Franklin Canal was estimated up to 620 ac-ft (or 305 ac-ft/mile).

- ***Results from the Current Meter Flow Measurements***

The total seepage losses for the irrigation season from current meter measurements were estimated by multiplying the estimated unit seepage losses by 243 days as shown in the last column of Table 4. Based on the estimated unit seepage losses results for irrigation season from current meter measurements as shown in Table 4, The total seepage losses for the first 5.29-mile reach of the Franklin Canal amount ranged from 4,620 to 10,384 ac-ft for irrigation season (833 to 1985 ac-ft per mile) (Table 4).

Table 3—Seepage Losses from Ponding Test

Ponding Site	Water Level Change Rate (ft/day)		Measured Unit Seepage Losses (cub ft/sq ft/day)	Estimated Unit Seepage Losses		Estimated Seepage Losses (ac-ft/ mile) for the Irrigation Season
				(cfs/mile)	(ac-ft/mile/day)	
Site 1 - Jan	Max	0.22	0.2130	0.4686	0.9294	225.83
	Min	0.11	0.1075	0.2364	0.4689	113.94
Site 2 - Jan	Max	0.35	0.3417	0.7518	1.4911	362.33
	Min	0.29	0.2875	0.6324	1.2543	304.80
Site 3 - Jan	Max	0.14	0.1369	0.3295	0.6536	158.82
	Min	0.12	0.1183	0.2848	0.5648	137.23
Site I - Nov	Max	0.21	0.20274	0.48816	0.9682	235.27
	Min	0.17	0.16443	0.39591	0.7852	190.81
Site II - Nov	Max	0.27	0.26299	0.63323	1.2559	305.19
	Min	0.25	0.24558	0.59131	1.1728	284.98

Table 4—Seepage losses from Current Meter Measurements (Franklin Canal)

Date	Measured Unit Seepage Losses (cub. ft/sq. ft/day)	Estimated Unit Seepage Losses		Seepage Losses for Irrigation Season (ac-ft/mile)
		(cfs/mile)	(ac-ft/mile/day)	
8/1/02	0.76	1.83	3.64	883.48
8/8/02	0.96	2.32	4.59	1115.75
9/18/02	1.71	4.12	8.17	1985.51
9/19/02	1.41	3.40	6.74	1638.43
10/2/02	1.47	3.53	7.00	1702.12
10/4/02	0.83	2.00	3.97	965.27

(3) Seepage Losses Comparison

- ***Ponding Tests Comparison***

For January ponding tests, Site 3 had the least variation in seepage loss in comparison with the other two sites possibly due to low permeability of canal beds and lining of some sections of the canal at this site. The results also indicate that seepage rates are reduced with the drop in water level. For November ponding tests, the same ponding site, called as Site I, showed less seepage losses compared to Site II probably due to the same reason as mentioned above. The results indicated that seepage losses varied from one location to another probably due to different soil type and hydraulic conditions.

Ponding tests Site 3 and Site I actually were located at the same location at Pendell Bridge, the results from different time (January vs. November) are thus comparable. Table 3 shows the comparison. The comparison indicates for the same location, estimated seepage losses for November are almost 50% higher than those for January. Although reasons for such increase are not clear, it is certain that more seepage losses can be expected than earlier estimation. Changes in hydraulic condition might be the main reason for higher seepage in November than in January. Secondly, after irrigation season, cleaner water coming down the canal had evidently removed some of the sediment seal from the bottom and thus may make the canal bed more permeable. Third, the vegetation evapotranspiration along the canal may contribute to additional losses too. It is recommended that more ponding tests be conducted to confirm such differences and their causes.

- ***Ponding Tests vs. Current Meter Flow Measurements***

From ponding tests results one can see that average seepage losses from ponding test are approximately ½ to 1/5 of those from current meter measurements. Such results differences may result from following factors:

a. Favorable hydraulic head difference between surface water and shallow groundwater increase seepage losses.
b. Vegetation evapotranspiration may contribute to additional losses.
c. Unsteady flow condition and measurement inaccuracy may also contribute to additional error in flow measurement.

First two factors may account for true additional losses. However, third factor may cause false estimate of the water losses. It is not clear how each factor contribute to the losses and to what extent each factor influence the seepage losses.

Conclusions and Recommendations

Based on the findings of seepage losses tests conducted, following conclusions and recommendations have been made:

a. Surface water seeps from the Franklin Canal at rates ranging from 0.7852 to 1.2559 ac-ft/mile/day based on the ponding tests or 3.64 to 8.17 ac-ft/mile/day from the current meter measurements. The total seepage losses for the irrigation season varied from 190.81 to 305.19 ac-ft/mile based on ponding tests or 883.48 to 1985.51 ac-ft/mile based on current meter measurements. The total estimated seepage losses for the first 5.29 miles was up to 1800 ac-ft from the ponding tests, or 10,384 ac-ft from current meter measurements.
b. By comparing ponding test results at Pendell Site (Site 3 and Site I for different time periods) before (January) and after (November) irrigation season, it was concluded that there was an almost 50% increase in seepage losses after irrigation season. Although reasons for such increase are not clear, it is certain that more seepage losses can be expected than earlier estimation. It is recommended that more ponding tests be conducted to confirm such differences and their causes. It was also noted that seepage varied spatially.
c. The results from current meter measurements show higher seepage losses than those from ponding tests. More studies should be conducted to confirm the true losses and eliminate false account for seepage losses resulting from measurement errors and inaccuracy of current meters.
d. Should the canal lining be prioritized, it is highly recommended that the first 3.26 miles from the Franklin Canal Heading to Fox Plaza be lined first because of higher potential for water savings.

References

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