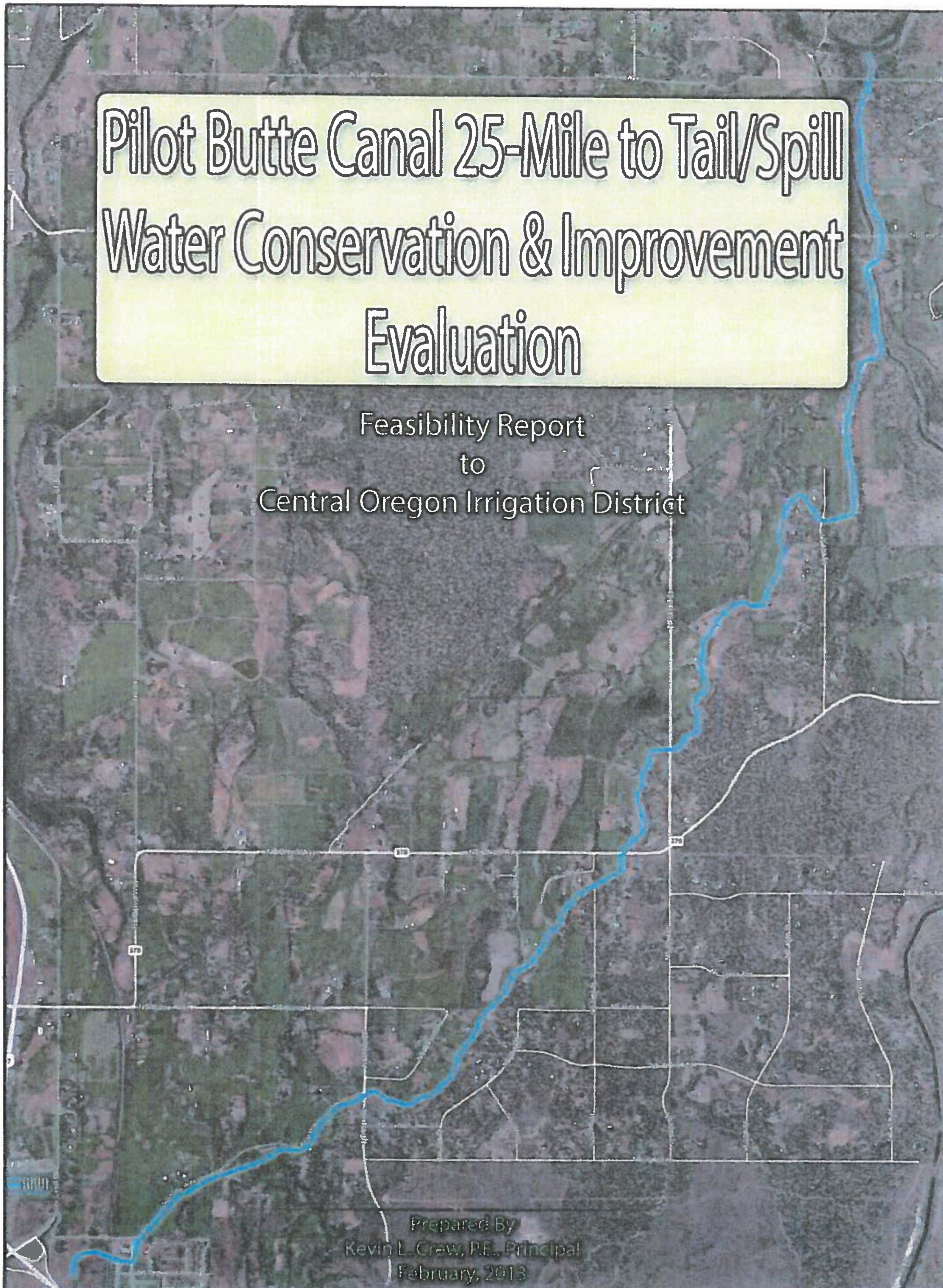
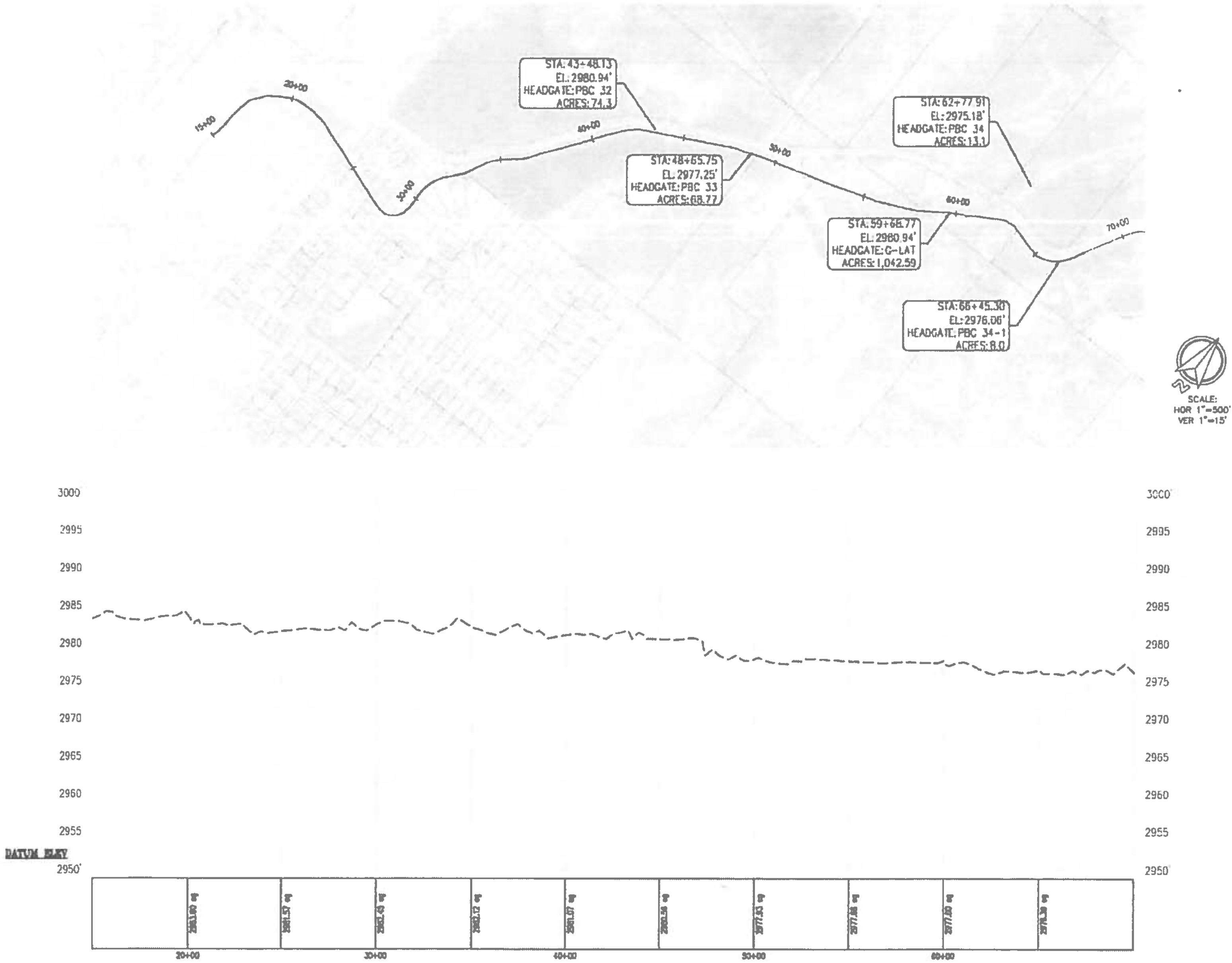
Pilot Butte Canal 25-Mile to Tail/Spill Water Conservation & Improvement Evaluation

Feasibility Report
to
Central Oregon Irrigation District



Prepared By
Kevin L. Crew, P.E., Principal
February, 2013



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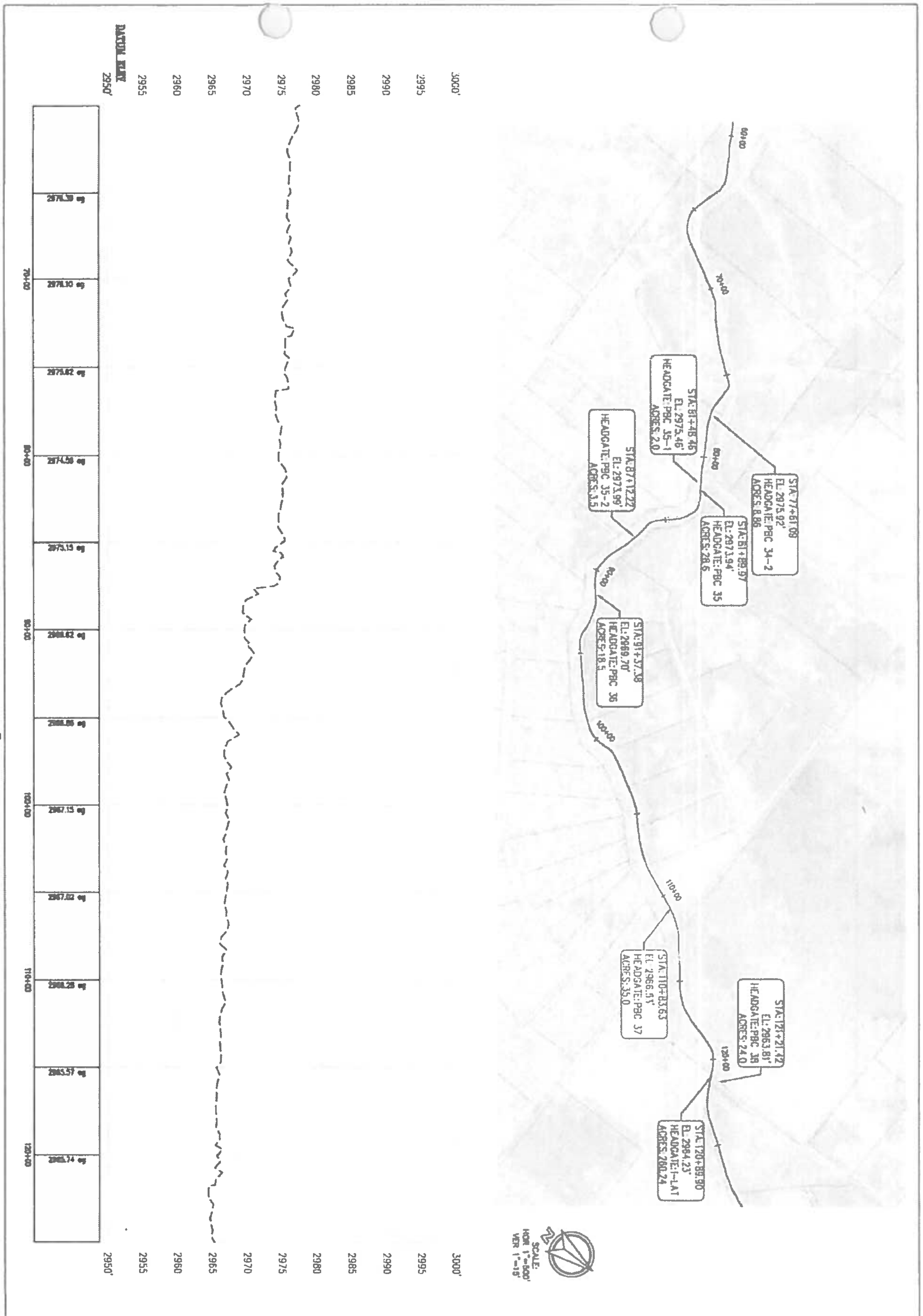
PILOT BUTTE CANAL
25 MILE WEIR TO TAIL

Exhibit A1
02.02.13



PILOT BUTTE CANAL
25 MILE WEIR TO TAIL

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Exhibit A2
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EXECUTIVE SUMMARY

The Central Oregon Irrigation District (COI) has incrementally implemented an aggressive program of water measurement that is improving its information and knowledge base of seepage and losses in its hundreds of miles of open canals. The Pilot Butte Canal 25-Mile Weir to Tail/Spill area is one such priority area that, if improved, provides a suite of benefits including conservation, reduced O&M, improved safety, and assistance in supplying North Unit Irrigation District (NUID) supplemental water to satisfy its Crooked River water rights. Within that reach of the Pilot Butte Canal, the peak flow is currently approximately 150 CFS and it serves approximately 4,000 Acres and additionally serves the Lone Pine Irrigation District and some tail flow to the North Unit Irrigation District.

The canal exhibits seepage issues that are visible along the alignment in adjacent fields and ditches. Through a series of measurements by COI in 2009, it was estimated that approximately 18.8 CFS was being lost to seepage and in 2012, a seepage evaluation indicated that approximately 11.3 CFS was being lost. In 2012, an Oregon Water Resources Department1069 Grant was approved to more completely study the seepage mitigation options, and associated costs and benefits of the 25-Mile Weir to Tail/Spill section of the Pilot Butte Canal.

During 2012, COI gathered field flow rate measurements and elevation measurements along the evaluation area that were incorporated into this study. Additionally, acreages of delivery, turnout locations, historic flow information, and tail flow information were incorporated from COI databases.

Base maps including plan and canal elevation profile were prepared an included hereunder for the entire alignment.

Seepage mitigation alternatives included geomembrane, shotcrete, and polyurea lining systems as well as a High Density Polyethylene (HDPE) piping alternative and study-level construction cost estimates were prepared for each option, based upon a 50-Year project life cycle. The least cost alternative was found to be geomembrane liner at approximately $15.1MM and the next lowest cost alternative was found to be piping at approximately $15.4MM. The range of all project options was $15.1MM to $25.5MM.

Benefits of the project were identified including conserved water in an amount of approximately 11 CFS, that translates to approximately 3,532 AF, as well as the benefits of reduced O&M, improved safety, and the ability to serve the Crooked River rights of the NUID. Given the current pricing for an acre-foot of conserved water, the project does not appear to generate enough cost benefit to fund the project cost. Given the broadspread benefits of the project, however, it may be considered of high enough value to attract multiple funding participants and therefore obtain the funding required.

Permitting for the project is considered minimal, with notification of agencies crossed (roads and RR), and application for a maintenance exemption from the US Army Corps of Engineers.

BACKGROUND

Over the last several years, the Central Oregon Irrigation District (COI) has incrementally implemented an aggressive program of water measurement that is improving its information and knowledge base of seepage and losses in its hundreds of miles of open canals. In conjunction with its Capital Improvement Program, the District is moving forward with such loss information to prioritize its efforts in mitigating the areas of highest water loss. The Pilot Butte Canal 25-Mile Weir to Tail/Spill area is one such priority area that, if improved, provides a suite of benefits including conservation, reduced O&M, improved safety, and assistance in supplying North Unit Irrigation District (NUID) supplemental water to satisfy its Crooked River water rights.

The Pilot Butte Canal, between the 25-Mile Weir and the tail end is an earthen/rock open canal ranging in bottom width from 20-Feet to 14-Feet in width and ranging in flow depth up to about 4-Feet. At its upper end, it currently conveys approximately 150 CFS peak, flow in the summer irrigation season and serves approximately 4,000 Acres, not including Lone Pine Irrigation District and the North Unit Irrigation District deliveries at the tail of the canal. The canal exhibits seepage issues that are visible along the alignment in adjacent fields and ditches. Through a series of measurements by COI in 2009, it was estimated that approximately 18.8 CFS was being lost to seepage and in 2012, a seepage evaluation indicated that approximately 11.3 CFS was being lost.

As the area was identified as having several potential broad-spread benefits, it was proposed for study under the Oregon Water Resources Department's 1069 Grant program and was approved under that program for the study that is contained herein in 2012.

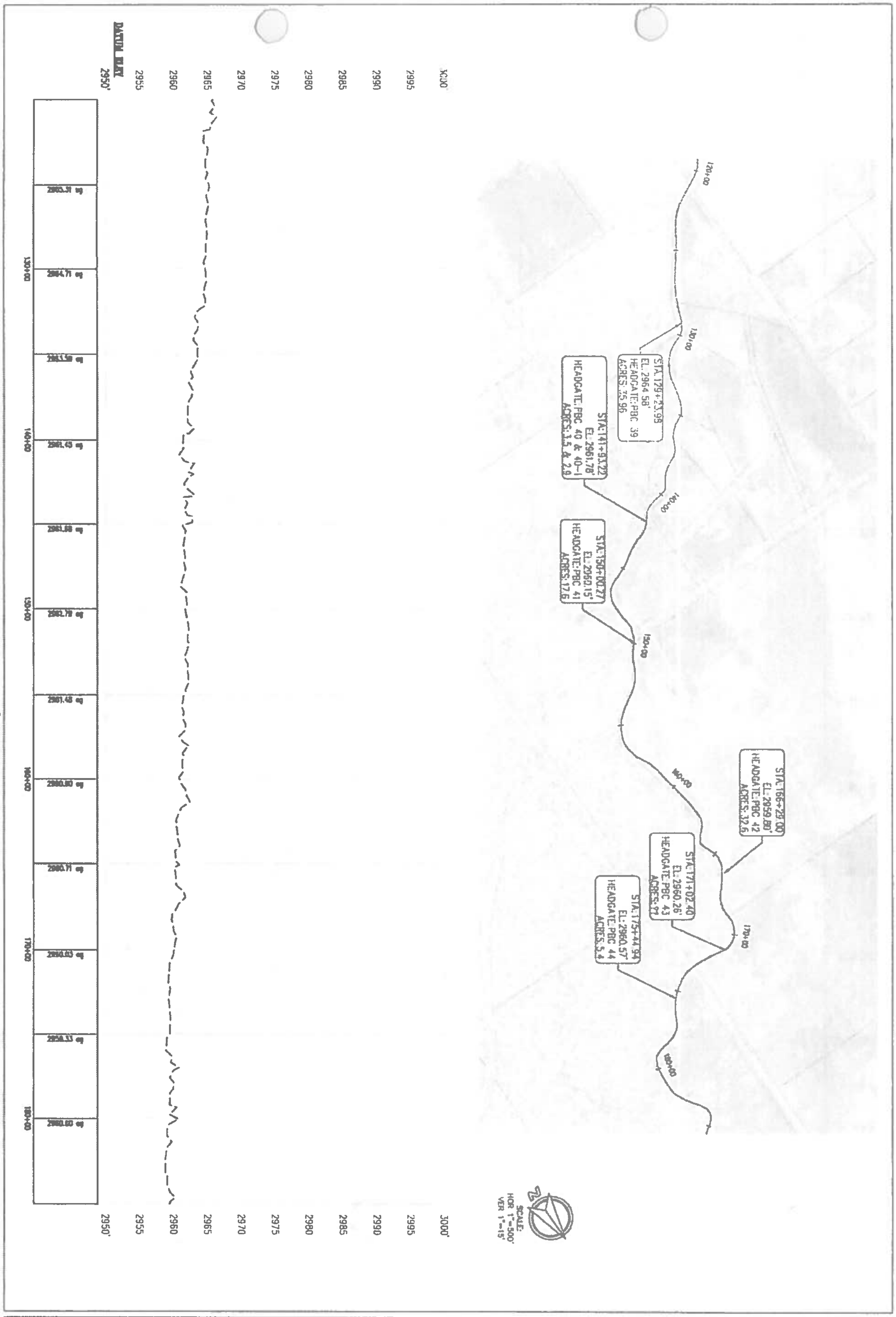
STUDY AREA BASE MAP AND RECONNAISSANCE-LEVEL PLAN AND PROFILE DEVELOPMENT

In 2004, the Central Oregon Irrigation District performed a GPS survey of a majority of its canal system using Trimble survey-grade equipment. Given that the canal alignment within the study area has not been altered in the time period since then, and since the canal bottom is generally cobbly rock and/or projecting basalt flows, the 2004 elevation data has been held as accurate and has been used for this study. In addition to this data, COI performed a 2012 GPS survey of the 42 patron headgates and 5 laterals within the approximate 5-mile study area. Horizontal locations, vertical elevations, and diversion flow rate estimates of these features were recorded. The horizontal locations were used to determine station location of these features along the alignment. Vertical elevations were used to generally verify the 2004 GPS data although the 2004 GPS datum was held for the purposes of this study.

In addition to the above data, Black Rock Consulting performed a site visit after the irrigation season concluded to measure approximate cross section geometries and various points along the canal. These were to be used in the development of the existing and proposed open-canal hydraulic capacity analysis described later in this study.

The base mapping that follows was developed for this report format at 1"=500' scale and provides the general alignment, centerline stationing, headgates and laterals along the canal and other general orientation features of the Pilot Butte Canal 25-mile to tail/spill study area. Canal invert profile was also provided based upon the COI 2004 GPS data described above.

What can be seen when evaluating the canal profile is that the canal is generally has a very low-gradient slope (i.e. s=0.001 to s=0.002) for a majority of the reach with the exception of a drop near 41st Street where basaltic flow projections have produced a steep gradient "falls" area.



PILOT BUTTE CANAL
25 MILE WEIR TO TAIL

Exhibit A3
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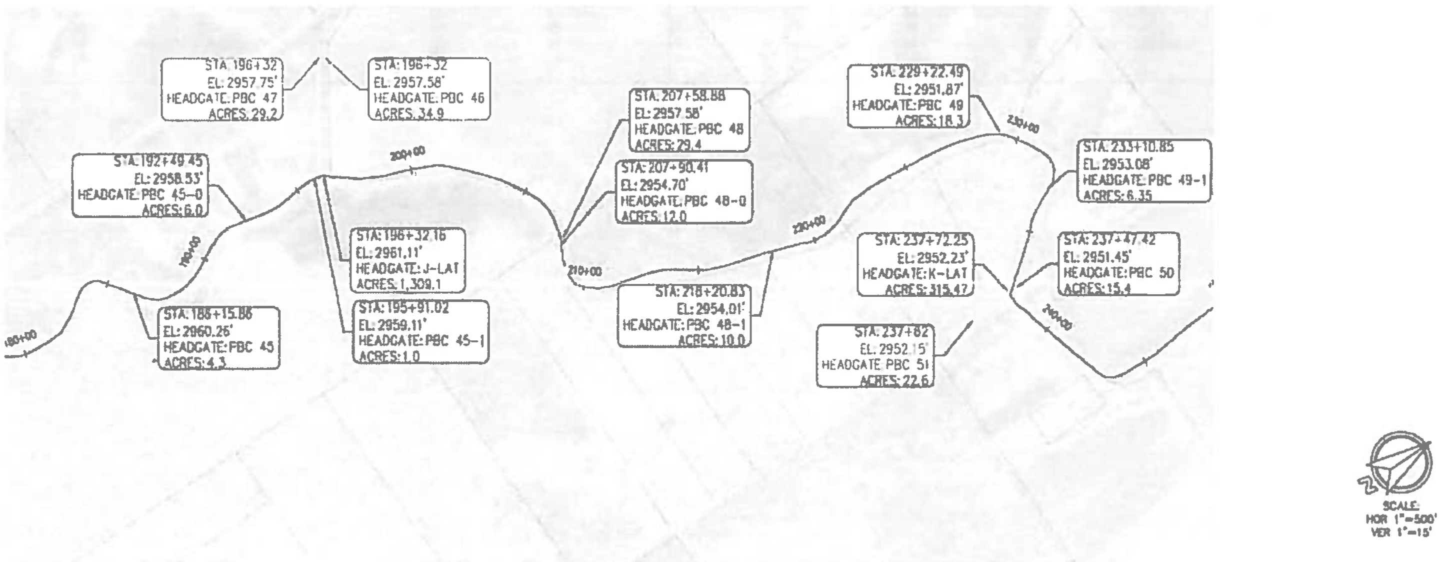

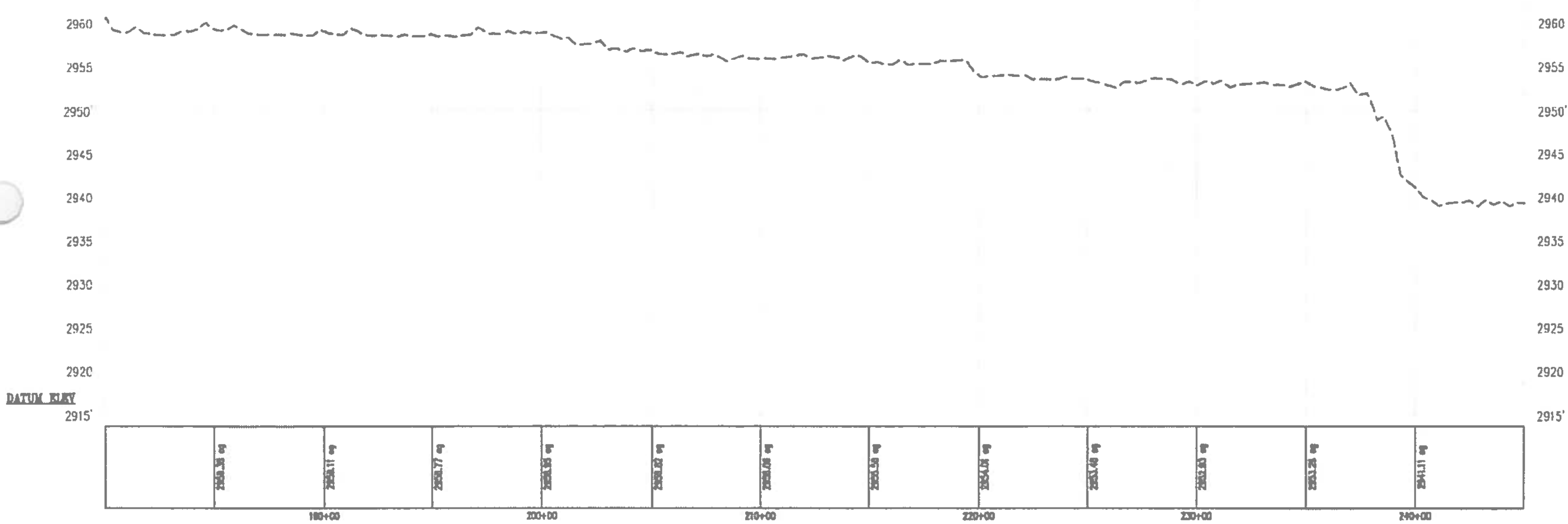

PILOT BUTTE CANAL
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Exhibit A4
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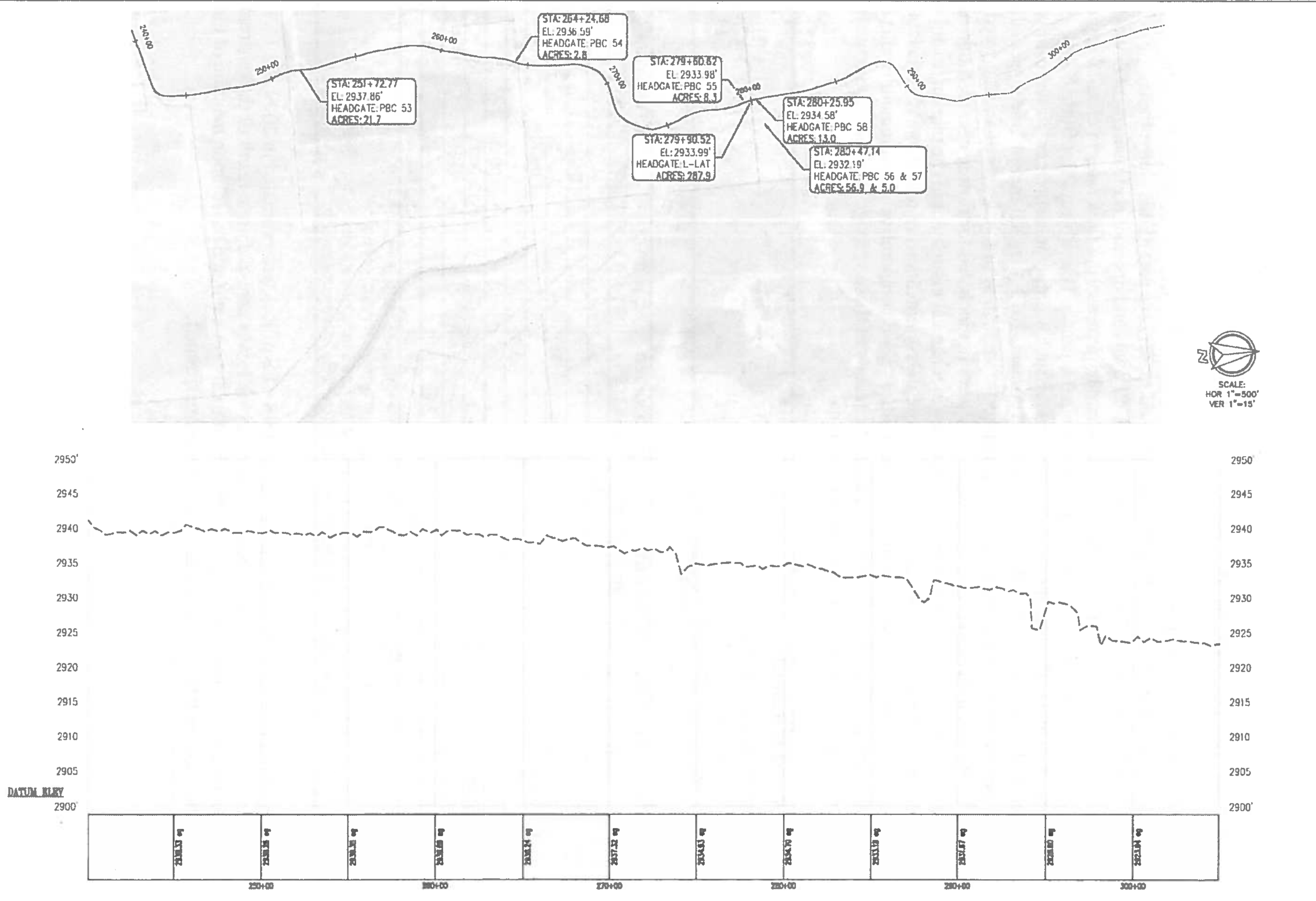

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PILOT BUTTE CANAL
25 MILE WEIR TO TAIL

Exhibit A5
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COI SEEPAGE LOSS INFORMATION

In 2009, COI performed initial seepage loss measurements through the approximate 5-mile long study area from the 25-mile weir to the tail/spill, and in 2012, as part of this study, these measurements were repeated (See Appendix A). COI owns and operates a measurement device known as a "doppler boat" that is effective and accurate in measuring flow rates in channel segments where there is substantial width and depth of flow in the canal. The subject Pilot Butte Canal segment studied has the appropriate characteristics for such accurate measurement in terms of width and depth. During the first set of measurements in August, 2012, the COI measurement specialists found that the canal measurement sections contained more than desirable levels of aquatic weed growth. Although measurements were taken, they were not included for further consideration in this evaluation. The canal was subsequently cleared by mechanical equipment in the measurement reaches and re-measured in September, 2012. These measurements were found to have much better statistical correlation and were included in this study as good comparative measurement results to the 2009 results. The following table indicates the results of these seepage loss measurements (refer to Base Mapping, above, for measurement locations):

25-MILE TO TAIL/SPILL
Estimation of Canal Losses
Per COID Measurement Data
2009/2012 Measurement Cycles

		2009		9/6/2012-9/7/12	
LOCATION	**STATION**	**FLOW RATE DAY OF TEST (CFS)**	**ESTIMATED LOSS (CFS)**	**FLOW RATE DAY OF TEST (CFS)**	**ESTIMATED LOSS (CFS)**
25-Mile Weir		131.0		115.2	
5th- Street				117.1	
G-Lateral		116.0	8.5	112.3	3.0
17th Street				95.8	3.2
Yucca		101.0	3.5		
PBC 37				99.5	-3.7
33rd-Street		94.0	0.3	89.3/90.6	5.2
41st-Street		68.0	2.0	65.2	2.5
Tail/Spill		47.0	4.5	47.0	1.1
		TOTAL=	**18.8**	**TOTAL=**	**11.3**

Notes:
1) 2009 Data measured at some differing locations to 2012 data.
2) 2012 Data measured after clearing weed growth for doppler boat.
3) Flow rates shown have been adjusted for flows through headgates and laterals
4) Where split flow rate is shown, two different days were measured.

The measurements indicate that approximately 18.8 CFS of loss was estimated in 2009 and 11.3 CFS in 2013. Based upon our experience, the varying losses assessed are a result of the inherent error in measuring flows (generally +/- 2%-5% of total flow rate) and based upon the time of the irrigation season that each set measurements were performed.

Given these factors, we recommend that 11 CFS be used as the initial loss estimate for this evaluation and that the District perform additional measurements to add to the data set and confidence in the loss estimate, as practical, prior to project implementation.

COI staff has developed a "shaping" model to adjust peak flow conserved to acre-feet conserved over an irrigation season cycle. The associated CFS to acre-feet conversion for 11 CFS to 3,532 Acre-Feet is as follows:

11.0 cfs conserved				
POD#11	Season 1 (61 Days)	Season 2 (30 Days)	Season 3 (123 Days)	Totals (214 Days)
Rate Conserved (CFS)				
1900	4.455	5.940	7.850	
1907			3.150	
Total	4.455	5.940	11.000	
Duty Conserved (AF) (Certificate 83571)				
1900	494.84	353.45	1915.85	2,764.14
1907			767.79	767.79
Total	494.84	353.45	2,683.64	3,531.93

SEEPAGE MITIGATION OPTIONS

Lining and piping are the two alternatives used extensively to mitigate seepage and evapotranspiration losses from open channel earthen conveyance canals. Generally, lining options have a lower initial cost but require more frequent maintenance and replacement intervals than piping options. For this reason, it is fundamental to project decision making to carefully consider the various lining and piping options based upon long term cost and maintenance. The following sections provide more detail regarding lining and piping considerations as they relate to this evaluation.

LINING CONSIDERATIONS

Canal lining is a challenging proposition that is even more difficult in Central Oregon. The significant seasonal and daily temperature swings, solar impacts, frost heave, wild and domestic animal impacts, and presence of shallow basalt all impact lining alternatives and selection. The U.S. Department of the Interior, Bureau of Reclamation prepared a report (R-02-03 *CANAL-LINING DEMONSTRATION PROJECT YEAR 10 FINAL REPORT, NOVEMBER, 2002)* addressing a multitude of lining alternatives that were tested locally in Central Oregon. What the report indicated was that Geomembrane with Concrete Cover, followed by Concrete alone, and then Exposed Geomembrane are in order of decreasing benefit/cost ratio.

In addition to this Bureau report, we have personally witnessed many of the test sites and issues with the various lining products on the local canals (Arnold ID, Ochoco ID, and Tumalo ID), including a Bureau lining failure site where a District's main canal was temporarily out of service as a result. Also, we prepared the fiber-mesh entrained shotcrete solution for an area of concern in another Central Oregon District. This system was installed 9 years ago and we have visited that site from time to time during that period. About that same time period the North Unit

Irrigation District installed approximately 11 miles of roller compacted concrete and shotcrete on its main canal from Bend toward Redmond that has also been observed from time to time. The North Unit Irrigation District continued its shotcrete lining project another 5-miles to the north on its main canal in 2012.

Based upon the Bureau report, and other experiences with Central Oregon projects as noted above, there are three primary alternatives that may be considered for lining the study area of the 25-Mile study area: Exposed Geomembrane, Concrete/Shotcrete, or Polyurea Over Geotextile.

Three specific lining alternatives were evaluated as indicated above based upon the Bureau findings and our personal experience with Central Oregon canal lining and piping projects:

- **Exposed Geomembrane** – exposed geomembranes are simply tarp-type liners. They are typically installed by smoothing out the bottom and sides of the canal with equipment and in some instances adding ¾"-0" gravel to prevent basalt rock protrusions from piercing the liner. The liner is typically anchored by digging trenches on each side of the canal about 1-2 feet back from the top of the bank and placing the tarp in those trenches and then backfilling them. Typically the millage thickness of the liner is 40-100 mils.

The benefit of such liner is that it is fairly simple to install with minimal equipment and outside contractor assistance. Geomembranes are flexible and therefore are not affected by the movements caused by frost heave. Also the initial cost of the material is low.

The issue that detracts from this material is its relative short life, potential for failure given lack of base support, its propensity to tear in the presence of animal hoof contact, the maintenance difficulty presented with silt/rock deposits, and that its chemical properties diminish, causing it to fail more readily. Also, any liner will generally increase canal flow velocities and personnel exit risk. We used a 15-year life span for this product and have used the Carlisle product as a typical lining example that has been readily used by irrigation districts in the West. Additionally, we estimate approximately 10 man-days per mile per year for maintenance of this product.

- **Concrete/Shotcrete** – Concrete and shotcrete have been used readily for canal liners in the West. The Central Oregon Irrigation District has experience with such liners in several locations within its systems. This product is typically installed by smoothing out the bottom and sides of the canal to some extent with equipment. Less preparation is typically necessary for hose-applied shotcrete than traditional structural concrete. The thickness of application and need for reinforcement varies depending upon the canal substrate.

The benefit of concrete or shotcrete liners is that they are fairly simple to install, although typically outside contractor assistance is necessary. The other benefit of concrete over geomembranes is that concrete is more tolerant to ultraviolet light from the sun. It is also more resistant to animal hoof damage than geomembranes.

The issues that detract from concrete or shotcrete liners is that the initial cost of these materials is higher than tarp-type liners. Secondly, concrete is a rigid material that tends to crack when surrounding ground moves or reduces support. With the annual freeze-thaw cycle present in Central Oregon, the canal ground, especially at the canal banks, tends to heave and recede, causing stress fractures in the concrete liner. These are typically mitigated by annual placement of elastomeric caulking in the cracks to prevent irrigation water from entering them, getting behind the concrete and ultimately causing concrete liner failure. For this reason, we vary from the Bureau report's estimated concrete liner longevity. In our opinion, shotecrete liners in Central Oregon canals will last about 20-25 years and structural concrete liners will last about 30-35 years. We also estimate approximately 10 man-days per mile per year for maintenance of this product.

- **Polyurea over Geotextile Membrane** – Polyurea is an elastomeric spray applied product that is gaining popularity for use on canals. In a typical earthen canal installation such as the 25-Mile study area, the rocky canal bottom would be filled with a graded layer of ¾"-0 crushed rock approximately 6-inches in thickness, whereas the more earthen/soil banks would be grubbed and shaped into a standard trapezoidal canal shape. Trenches would be excavated on each side of the top of the bank, a geotextile membrane would be installed across the canal and into the trenches on each side (and then trenches backfilled), and finally, the polyurea would be spray applied to the geotextile membrane.

Polyurea (90 mil +/-) is a two part product that must be applied by someone certified and/or trained in the application. In a canal situation the build-up would be to an approximate minimum of 90-mils and thicker at the geomembrane seams.

The benefit of Polyurea, especially in the Central Oregon area with severe temperature swings and winter frost heave is that the product will elongate over 600%. This allows the bridging of moving gaps and adjustment of substrate without tearing the product. The additional benefit of sprayed-on liner is that it ends up being a monolithic product versus a product with many seams as in tarp-type liners.

The issues that detract from polyurea are its cost in comparison to other liners and that due to its exposure it is likely to deteriorate due to UV and it is susceptible to animal damage as an exposed flexible liner.

PIPE SIZING AND PIPING CONSIDERATIONS

Piping is a viable and much used solution to canal seepage mitigation. In Central Oregon, buried piping provides a stable environment much more protected from the harsh climate than exposed liner alternatives. Although many varieties of pipe materials have been used on canals in Central Oregon over the years including reinforced concrete, corrugated metal, ductile iron, spiral rib metal, coated and lined steel pipe, and reinforced concrete box culverts, the advent of High Density Polyethylene (HDPE) pipe has provided a product that works very well as a solution to large and small diameter and low and high head canal piping situations. HDPE is more abrasion resistant than steel, it is light weight, may be arced into a radius during installation, and may be welded into a fully sealed and watertight installation. For the purposes of this study, HDPE was assumed as the piping material of choice although other alternatives may be considered during final design and project bidding.

The estimated HDPE pipe diameter for this project study area based upon a Hazen-Williams Coefficient of (C=130), the rough field profile developed from the COI GPS data gathered, and peak flow rates as indicated in the table below. Were HDPE pipe is indicated, the product would be a profile wall HDPE low-head product such as Spirolite or Weholite. Where a DR rating is indicated, the product would be solid-wall fusion-welded HDPE pipe with a minimum pressure rating of 50 PSI.

Two scenarios were evaluated for sizing pipe and development of associated cost estimating. First, the canal section was evaluated at the current capacity and historical tail delivery to NUID of 25 CFS, maximum. Second, the section was evaluated with an additional 25 CFS of tail capacity (for a total of 50 CFS of tail capacity) to emulate a 50 CFS delivery to NUID at the tail of the system. This increase would approximately serve the delivery requirement to meet the Crooked River rights served by NUID.

PILOT BUTTE CANAL - 25-MILE WEIR TO TAIL/SPILL STUDY													
Central Oregon Irrigation District													
With 25 CFS NUID Tail Capacity													
February, 2013	Black Rock Consulting				9 GPM/Acre		130 HWC						
Segment Description	Station Start (FT)	Elevation Start (FT)	Station End (FT)	Elevation End (FT)	Segment Length (FT)	Total Length (FT)	Elevation Differential (FT)	Current HGL Slope	Turnout Acres	Segment Flow Rate (CFS)	Hydraulic Segment Length	Pipe Material	Inside Diameter (IN)
Start at 25-Mile Weir	1500	2984.5	4313	2980.9	2813	2813				152.6		HDPE	78
PBC 32	4313	2980.9	4831	2977.3	518	3331			74.3	151.1		HDPE	78
PBC 33	4831	2977.3	5934	2981	1103	4434			68.8	149.8		HDPE	78
G-Lateral	5934	2981	6610	2976.1	676	5110	3.5	0.000685	1042.6	128.9	5,110	HDPE	78
PBC 34-1	6610	2976.1	7726	2975.9	1116	6226			8	128.7		HDPE	66
PBC 34-2	7726	2975.9	8114	2975.5	388	6614			8.9	128.5		HDPE	66
PBC 35-1	8114	2975.5	8155	2973.9	41	6655			2	128.5		HDPE	66
PBC 35	8155	2973.9	8677	2974	522	7177			28.6	127.9		HDPE	66
PBC 35-2	8677	2974	9102	2969.7	425	7602			3.5	127.8		HDPE	66
PBC 36	9102	2969.7	11049	2966.5	1947	9549			18.5	127.5		HDPE	66
PBC 37	11049	2966.5	12055	2964.2	1006	10555	14.5	0.002663	35	126.8	5,445	HDPE	66
I-LAT	12055	2964.2	12086	2963.8	31	10586			260.2	121.6		HDPE	60
PBC 38	12086	2963.8	12889	2964.6	803	11389			24	121.1		HDPE	60
PBC 39	12889	2964.6	14158	2961.8	1269	12658			36	120.4		HDPE	60
PBC 40/40-1	14158	2961.8	14965	2960.2	807	13465			6.4	120.2		HDPE	60
PBC 41	14965	2960.2	16594	2959.8	1629	15094			17.6	119.9		HDPE	60
PBC 42	16594	2959.8	17067	2960.3	473	15567			32.6	119.2		HDPE	60
PBC 43	17067	2960.3	17510	2960.6	443	16010			0	119.2		HDPE	60
PBC 44	17510	2960.6	18581	2960.3	1071	17081	5.9	0.000904	5.4	119.1	6,526	HDPE	60
PBC 45	18581	2960.3	19214	2958.5	633	17714			4.3	119.0		HDPE	51.208
PBC 45-0	19214	2958.5	19556	2959.1	342	18056			6	118.9		HDPE	51.208
PBC 45-1	19556	2959.1	19597	2961.1	41	18097			1	118.9		HDPE	51.208
J-LAT	19597	2961.1	19600	2957.8	3	18100	3	0.002944	1309.1	92.6	1,019	HDPE	51.208
PBC 47	19600	2957.8	19601	2957.6	1	18101			29.2	92.1		54DR32.5	51.208
PBC 46	19601	2957.6	20724	2957.6	1123	19224			34.9	91.4		54DR32.5	51.208
PBC 48	20724	2957.6	20755	2954.7	31	19255			29.4	90.8		54DR32.5	51.208
PBC 48-0	20755	2954.7	21784	2954	1029	20284			12	90.5		54DR32.5	51.208
PBC 48-1	21784	2954	22888	2951.9	1104	21388			10	90.3		54DR32.5	51.208
PBC 49	22888	2951.9	23276	2953.1	388	21776			18.3	90.0		54DR32.5	51.208
PBC 49-1	23276	2953.1	23712	2951.5	436	22212			6.4	89.8		54DR32.5	51.208
PBC 50	23712	2951.5	23737	2952.2	25	22237			15.4	89.5		54DR32.5	51.208
K-LAT	23737	2952.2	23740	2952.1	3	22240			315.5	83.2		54DR32.5	51.208
PBC 51	23740	2952.1	25138	2937.9	1398	23638			22.6	82.7		54DR32.5	51.208
PBC 53	25138	2937.9	26390	2936.6	1252	24890	23.2	0.003417	21.7	82.3	6,790	54DR32.5	51.208
PBC 54	26390	2936.6	27926	2934	1536	26426			2.8	82.3		48DR41	45.52
PBC 55	27926	2934	27956	2934	30	26456			8.3	82.1		48DR41	45.52
L-LAT	27956	2934	27991	2934.6	35	26491			287.9	76.3		48DR41	45.52
PBC 58	27991	2934.6	28012	2932.2	21	26512	3.3	0.002035	13	76.1	1,622	48DR41	45.52
PBC 56/57	28012	2932.2							61.9	75.8			
DELIVERIES BELOW SPILL									102.5	74.6			
Lone Pine ID									47.5 CFS	72.5			
DESIRED TAIL CAPACITY										25.0			
								TOTAL	3984.6	3874.3	26,512		

PILOT BUTTE CANAL - 25-MILE WEIR TO TAIL/SPILL STUDY

Central Oregon Irrigation District
With 50 CFS NUID Tail Capacity
February, 2013 — Black Rock Consulting

Segment Description	Station Start (FT)	Elevation Start (FT)	Station End (FT)	Elevation End (FT)	Segment Length (FT)	Total Length (FT)	Elevation Differential (FT)	Current HGL Slope	Turnout Acres	Segment Flow Rate (CFS)	Hydraulic Segment Length	Pipe Material	Inside Diameter (IN)
					9 GPM/Acre		130 HWC						
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G-Lateral	5934	2981	6610	2976.1	676	5110	3.5	0.0006849	1042.6	153.9	5,110	HDPE	84
PBC 34-1	6610	2976.1	7726	2975.9	1116	6226			8	153.7		HDPE	72
PBC 34-2	7726	2975.9	8114	2975.5	388	6614			8.9	153.5		HDPE	72
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PBC 37	11049	2966.5	12055	2964.2	1006	10555	14.5	0.002663	35	151.8	5,445	HDPE	72
I-LAT	12055	2964.2	12086	2963.8	31	10586			260.2	146.6		HDPE	66
PBC 38	12086	2963.8	12889	2964.6	803	11389			24	146.1		HDPE	66
PBC 39	12889	2964.6	14158	2961.8	1269	12658			36	145.4		HDPE	66
PBC 40/40-1	14158	2961.8	14965	2960.2	807	13465			6.4	145.2		HDPE	66
PBC 41	14965	2960.2	16594	2959.8	1629	15094			17.6	144.9		HDPE	66
PBC 42	16594	2959.8	17067	2960.3	473	15567			32.6	144.2		HDPE	66
PBC 43	17067	2960.3	17510	2960.6	443	16010			0	144.2		HDPE	66
PBC 44	17510	2960.6	18581	2960.3	1071	17081	5.9	0.0009041	5.4	144.1	6,526	HDPE	66
PBC 45	18581	2960.3	19214	2958.5	633	17714			4.3	144.0		HDPE	54
PBC 45-0	19214	2958.5	19556	2959.1	342	18056			6	143.9		HDPE	54
PBC 45-1	19556	2959.1	19597	2961.1	41	18097			1	143.9		HDPE	54
J-LAT	19597	2961.1	19600	2957.8	3	18100	3	0.0029441	1309.1	117.6	1,019	HDPE	54
PBC 47	19600	2957.8	19601	2957.6	1	18101			29.2	117.1		54DR32.5	51.208
PBC 46	19601	2957.6	20724	2957.6	1123	19224			34.9	116.4		54DR32.5	51.208
PBC 48	20724	2957.6	20755	2954.7	31	19255			29.4	115.8		54DR32.5	51.208
PBC 48-0	20755	2954.7	21784	2954	1029	20284			12	115.5		54DR32.5	51.208
PBC 48-1	21784	2954	22888	2951.9	1104	21388			10	115.3		54DR32.5	51.208
PBC 49	22888	2951.9	23276	2953.1	388	21776			18.3	115.0		54DR32.5	51.208
PBC 49-1	23276	2953.1	23712	2951.5	436	22212			6.4	114.8		54DR32.5	51.208
PBC 50	23712	2951.5	23737	2952.2	25	22237			15.4	114.5		54DR32.5	51.208
K-LAT	23737	2952.2	23740	2952.1	3	22240			315.5	108.2		54DR32.5	51.208
PBC 51	23740	2952.1	25138	2937.9	1398	23638			22.6	107.7		54DR32.5	51.208
PBC 53	25138	2937.9	26390	2936.6	1252	24890	23.2	0.0034168	21.7	107.3	6,790	54DR32.5	51.208
PBC 54	26390	2936.6	27926	2934	1536	26426			2.8	107.3		48DR41	45.52
PBC 55	27926	2934	27956	2934	30	26456			8.3	107.1		48DR41	45.52
L-LAT	27956	2934	27991	2934.6	35	26491			287.9	101.3		48DR41	45.52
PBC 58	27991	2934.6	28012	2932.2	21	26512	3.3	0.0020345	13	101.1	1,622	48DR41	45.52
PBC 56/57	28012	2932.2							61.9	100.8			
DELIVERIES BELOW SPILL									102.5	99.6			
Lone Pine ID									47.5 CFS	97.5			
DESIRED TAIL CAPACITY										50.0			
								TOTAL	3984.6	4799.3	26,512		

The benefit of HDPE piping is that it is a very abrasion resistant material, that when buried is essentially maintenance free. It has a very low friction loss component and its life span is lengthy. Based upon its use domestically and abroad, and our personal experience with the product in Central Oregon, we are comfortable giving it a 60-year life expectancy, but could just as easily say 100-years or more. For the purposes of this report and lining alternative comparisons, we will use 50-years.

There are several differences between the Weholite HDPE, Spirolite HDPE and the Solid Wall Fusion Welded HDPE pipes. Weholite is a proprietary product currently manufactured in Canada by KWH pipe. It has been used on several successful projects in Central Oregon. It is a profile wall pipe and does not arc as readily as solid wall pipe, therefore angle fittings are required at trench angles. Spirolite is manufacted by IPF in Texas. It is a gasketed bell and spigot product that does not require welding. Testing of the product would be required to insure its pressure resistance to 15 PSI. The same would be true for Weholite. With Weholite, all joints would be fully welded by a factory robotic extrusion welder. Solid wall fusion welded HDPE pipe is manufactured by a variety of manufacturers in the USA and abroad. It is being used extensively in the USA and in irrigation district systems. This pipe is readily bendable. Joints are fusion welded and may be welded by factory personnel or certified District personnel.

LINER CAPACITY CONSIDERATIONS

Given the GPS data gathered by COI and canal cross section measurements at approximately 10 locations along the project area, a concept-level calibration of capacity was performed for the existing canal and based upon the addition of the various liner options (geomembrane, shotcrete, and polyurea). An estimated manning's n (canal roughness) value from literature and calibration was developed for the existing canal and was approximated to be n=0.025. Given estimated manning's n roughness coefficients for geomembrane, shotcrete and polyurea of n=0.015, n=0.018, and n=0.015, respectively, it was found that the additional capacity of the canal would likely increase enough to pass the additional tail water required to meet the full 50 CFS goal for the geomembrane and polyurea products. For the shotcrete product, increasing canal cross section capacity in certain constricted areas would likely be necessary due to the roughness and thickness of shotcrete liner material. Final design survey and final detailed modeling and design would be required to more accurately estimate final canal capacity.

RECONNAISSANCE LEVEL COST ESTIMATES

The five alternatives were compared on a cost basis given a 50 year project life cycle and based upon 2012 costs. The cost of membrane lining was obtained by the pacific northwest Carlisle representative for a 60-mil membrane liner system. The cost of concrete/shotcrete lining was developed using extrapolated costs from the NUID lining project (completed in 2012). HDPE pipe costs were obtained from suppliers for low-head Spirolite, low-head Weholite pipe and SDR 41/32.5 HDPE pipe, and values for the installation were taken from recent bidding/construction experience in Central Oregon. We must emphasize that this pricing is based upon this research and sources. Pipe pricing can be very volatile. HDPE pricing is strongly influenced by oil pricing as it is produced from petroleum. Shotcrete pricinig can also be very volatile. 6 years ago, standard concrete sold for bout $60/CY. Today it is over $110/CY. Shotcrete with fiber mesh in it will sell for approximately $140/CY today. HDPE and the Carlisle or Firestone liners are petroleum based products. Prices are lower recently, but have been significantly inflated over the last few years. The caution is that as the District moves forward the selected alternative will likely need to be repriced and adjusted prior to construction.

25-MILE WEIR TO TAIL/SPILL				
PRELIMINARY/CONCEPTUAL CONSTRUCTION COST ESTIMATE				
GEOMEMBRANE/GEOTEXTILE LINER	**50-YR LIFE CYCLE**			
BLACK ROCK CONSULTING				
Construction Item	**Quantity**	**Units**	**Cost/Unit**	**Subtotal Cost**
Earthwork and General Construction				
1. Mobilization	10	%	of Total	$311,425
2. Clearing and Grubbing	1	LS	$200,000	$200,000
3. Excavation, Backfill, Compaction of Bedding and Banks	10,000	CY	$19	$190,000
4. Road and RR Crossings (Assumes Notification Only)	7	EA	$250	$1,750
5. 3/4"-0 Bedding and Grading	9,000	CY	$25	$225,000
EPDM Liner				
6. 6 oz. Geotextile w/ Installation	26,600	LF	$20	$532,000
7. 60 Mil EPDM Liner System installed/Taped/Edge Bckfll	26,600	LF	$70	$1,862,000
Connections and Appurtenances				
8. Connections at Headgates and Laterals	47	EA	$1,500	$70,500
9. Project Start Concrete Cutoff Wall	1	LS	$25,000	$25,000
10. Tail Connections at Spill	1	LS	$8,000	$8,000
Contingency (Study Level)	25	%	of Construction	$856,419
Final Engineering, Permitting, Construction Management	4	%	of subtotal	$171,284
Geotechnical				$10,000
Design Survey				$10,000
			SUBTOTAL	**$4,473,378**
11. 50-YR Maintenance Cycle	50	EA	$20,000	$1,000,000
12. 15-Year Replacement Cycle (Liner and Geotextile)	3	EA	$3,221,875	$9,665,625
			TOTAL 50-YR	**$15,139,003**

25-MILE WEIR TO TAIL/SPILL				
PRELIMINARY/CONCEPTUAL CONSTRUCTION COST ESTIMATE				
SHOTCRETE LINER	**50-YR LIFE CYCLE**			
BLACK ROCK CONSULTING				
Construction Item	**Quantity**	**Units**	**Cost/Unit**	**Subtotal Cost**
Earthwork and General Construction				
1. Mobilization	10	%	of Total	$560,100
2. Clearing and Grubbing	1	LS	$200,000	$200,000
3. Excavation, Backfill, Compaction of Bedding and Banks	10,000	CY	$19	$190,000
4. Road and RR Crossings (Assumes Notification Only)	7	EA	$1,000	$7,000
5. 3/4"-0 Banks and Selected Invert Areas	12,500	CY	$25	$312,500
Shotcrete Liner				
6. Fibermesh Shotcrete - Applied at 4" Thickness	26,600	LF	$180	$4,788,000
Connections and Appurtenances				
7. Connections at Headgates and Laterals	47	EA	$1,500	$70,500
8. Project Start Concrete Cutoff Wall	1	LS	$25,000	$25,000
9. Tail Connections at Spill	1	LS	$8,000	$8,000
Contingency (Study Level)	25	%	of Construction	$1,540,275
Final Engineering, Permitting, Construction Management	4	%	of subtotal	$308,055
Geotechnical				$15,000
Design Survey				$10,000
			SUBTOTAL	**$8,034,430**
10. 50-YR Maintenance Cycle	50	EA	$20,000	$1,000,000
11. 20-Year Replacement Cycle (Remove and Replace)	2	EA	$6,614,375	$13,228,750
			TOTAL 50-YR	**$22,263,180**

25-MILE WEIR TO TAIL/SPILL				
PRELIMINARY/CONCEPTUAL CONSTRUCTION COST ESTIMATE				
POLYUREA OVER GEOTEXTILE	**50-YR LIFE CYCLE**			
BLACK ROCK CONSULTING				
Construction Item	**Quantity**	**Units**	**Cost/Unit**	**Subtotal Cost**
Earthwork and General Construction				
1. Mobilization	10	%	of Total	$590,725
2. Clearing and Grubbing	1	LS	$200,000	$200,000
3. Excavation, Backfill, Compaction of Bedding and Banks	10,000	CY	$19	$190,000
4. Road and RR Crossings (Assumes Notification Only)	7	EA	$250	$1,750
5. 3/4"-0 Bedding and Grading	9,000	CY	$25	$225,000
Polyurea Liner System				
6. 6 oz. Geotextile w/ Installation	26,600	LF	$20	$532,000
7. 90 Mil High Pressure Polyurea	26,600	LF	$175	$4,655,000
Connections and Appurtenances				
8. Connections at Headgates and Laterals	47	EA	$1,500	$70,500
9. Project Start Concrete Cutoff Wall	1	LS	$25,000	$25,000
10. Tail Connections at Spill	1	LS	$8,000	$8,000
Contingency (Study Level)	25	%	of Construction	$1,624,494
Final Engineering, Permitting, Construction Management	4	%	of subtotal	$324,899
Geotechnical				$10,000
Design Survey				$10,000
			SUBTOTAL	**$8,467,368**
11. 50-YR Maintenance Cycle	50	EA	$20,000	$1,000,000
12. 20-Year Replacement Cycle (Liner and Geotextile)	2	EA	$6,713,125	$13,426,250
			TOTAL 50-YR	**$22,893,618**

25-MILE WEIR TO TAIL/SPILL				
PRELIMINARY/CONCEPTUAL CONSTRUCTION COST ESTIMATE				
CANAL PIPING - 25 CFS TO TAIL		**50-YR LIFE CYCLE**		
BLACK ROCK CONSULTING				
Construction Item	**Quantity**	**Units**	**Cost/Unit**	**Subtotal Cost**
Earthwork and General Construction				
1. Mobilization	10	%	of Total	$1,006,432.50
2. Clearing and Grubbing (Incl Bridge Removal)	1	LS	$160,000.00	$160,000.00
3. Excavation, Backfill, Compaction of Pipeline	160,000	CY	$20.00	$3,200,000.00
4. Road and RR Crossings (Assumes Processing Only)	7	EA	$8,000.00	$56,000.00
5. Restoration/Seeding	1	LS	$70,000.00	$70,000.00
Pipe (HDPE)				
6. 78" Dia. Pipe Including Welding and Delivery	5,110	LF	$350.00	$1,788,500.00
7. 66" Dia. Pipe Including Welding and Delivery	5,445	LF	$260.00	$1,415,700.00
8. 60" Dia. Pipe Including Welding and Delivery	6,526	LF	$230.00	$1,500,980.00
9. 54" DR32.5 Pipe Including Welding and Delivery	7,809	LF	$155.00	$1,210,395.00
10. 48" DR41 Pipe Including Welding and Delivery	1,622	LF	$125.00	$202,750.00
TOTAL	26,512	LF		
Pipe Appurtenances				
11. Conn. and Appurts. to Pipe	1	LS	$20,000.00	$20,000.00
12. Furnish and Install Air/Vacuum Relief Assemblies	12	EA	$10,000.00	$120,000.00
13. Furnish and install turnout assemblies, complete	47	EA	$5,000.00	$235,000.00
Proposed Forebay				
14. Furnish and Install Reinforced Concrete Intake/Outlet	100	CY	$600.00	$60,000.00
15. Furnish and Install Intake Trashrack	1	LS	$25,000.00	$25,000.00
Contingency	25	%	of Construction	$2,576,467.20
Final Engineering, Permitting, Construction Management	4	%	of subtotal	$545,888.99
Geotechnical				$15,000.00
Design/Construction Survey				$35,000.00
			SUBTOTAL	**$14,243,114**
16. 50-YR Maintenance Cycle	50	EA	$2,500	$125,000
			TOTAL 50-YR	**$14,368,114**

25-MILE WEIR TO TAIL/SPILL
PRELIMINARY/CONCEPTUAL CONSTRUCTION COST ESTIMATE
CANAL PIPING - 50 CFS TO TAIL
BLACK ROCK CONSULTING

50-YR LIFE CYCLE

Construction Item	Quantity	Units	Cost/Unit	Subtotal Cost
Earthwork and General Construction				
1. Mobilization	10	%	of Total	$1,078,945.00
2. Clearing and Grubbing (Incl Bridge Removal)	1	LS	$160,000.00	$160,000.00
3. Excavation, Backfill, Compaction of Pipeline	160,000	CY	$20.00	$3,200,000.00
4. Road and RR Crossings (Assumes Processing Only)	7	EA	$8,000.00	$56,000.00
5. Restoration/Seeding	1	LS	$70,000.00	$70,000.00
Pipe (HDPE)				
6. 84" Dia. Pipe Including Welding and Delivery	5,110	LF	$400.00	$2,044,000.00
7. 72" Dia. Pipe Including Welding and Delivery	5,445	LF	$300.00	$1,633,500.00
8. 66" Dia. Pipe Including Welding and Delivery	6,526	LF	$260.00	$1,696,760.00
9. 54" Dia. Pipe Including Welding and Delivery	1,019	LF	$210.00	$213,990.00
10. 54" DR32.5 Pipe Including Welding and Delivery	6,790	LF	$155.00	$1,052,450.00
11. 48" DR41 Pipe Including Welding and Delivery	1,622	LF	$125.00	$202,750.00
TOTAL	26,512	LF		
Pipe Appurtenances				
12. Conn. and Appurts. to Pipe	1	LS	$20,000.00	$20,000.00
13. Furnish and Install Air/Vacuum Relief Assemblies	12	EA	$10,000.00	$120,000.00
14. Furnish and install turnout assemblies, complete	47	EA	$5,000.00	$235,000.00
Proposed Forebay				
15. Furnish and Install Reinforced Concrete Intake/Outlet	100	CY	$600.00	$60,000.00
16. Furnish and Install Intake Trashrack	1	LS	$25,000.00	$25,000.00
Contingency	25	%	of Construction	$2,762,099.20
Final Engineering, Permitting, Construction Management	4	%	of subtotal	$585,219.77
Geotechnical				$15,000.00
Design/Construction Survey				$35,000.00
			SUBTOTAL	$15,265,714
17. 50-YR Maintenance Cycle	50	EA	$2,500	$125,000
			TOTAL 50-YR	$15,390,714

The above reconnaissance level cost estimate includes procurement, installation and maintenance of each product for a period of 50-years.

The above reconnaissance level cost estimate assumes property owner cooperation, replacement of any and all crossings by others/agencies and/or private parties, and US ACOE maintenance exemption. Equipment and material costs other than pipe should be considered close to actual costs for a construction contractor to perform the work. A 25% contingency was included in each estimate to cover uncertainty commensurate with a study level cost estimate. As design proceeds with any or all work, cost estimating should be refined and the associated contingency may be reduced. Estimating also includes budget estimates for engineering, surveying and geotechnical services that will likely be required.

PROJECT BENEFITS

The project would provide significant benefits in several ways:

1) To provide additional capacity to convey water to the NUID and thus cover the Crooked River water right capacity currently delivered by pumping by NUID from the Crooked River.

2) To reduce operation and maintenance given a selected piping option. Given liner options, annual maintenance cycles would likely increase current O&M costs.

3) To conserve water lost to seepage in an estimated amount of 3,532 AF.

4) To reduce safety risks given a selected piping option.

Although the value changes over time, the value of conserved water currently ranges from $500/AF to nearly $2,000/AF given the perceived value of the conservation and willingness of investors, whether public or private, to compensate for the in-stream water.

PERMITS AND PERMITTING

- **Roads and Railroad** – The Central Oregon Irrigation District generally has prior rights due to the age of its Federal Easements and original installation date. For the purposes of this study, it has been assumed that all crossings of public right-of–way and railroads will be based upon notification of the agency responsible for the road or railroad to be crossed. Where possible, design will minimize impacts to public rights-of-way, however, if trenched excavation is required, the agency will be responsible for replacement of its road section to conform with its standards.
- **US Army Corps of Engineers** - It has been the experience of COI that canal piping and/or lining would be considered an exemption by the USACOE under its current rules and regulations. COI would apply for a permit exemption prior to construction.
- **Local Bridge Crossings** – COI would coordinate with its patrons and other parties along the canal to remove and reset private bridges as necessary for construction. Under a piping alternative, bridges may be replaced by simply backfilling the canal and pipe installation with competent material and allowing for at-grade crossing of the canal through COI crossing permit procedures.

No other local, State or Federal permits are known to be necessary prior to implementation of the contemplated improvements.

SUMMARY RECOMMENDATION FOR PROJECT APPROACH

It is recommended that the District review the information contained in this report and then evaluate the funding potential for the project, whether in phases or in total. Given the current value of in-stream water, and the absence of any other funding, it does not appear that the financial benefit is commensurate with the project 50-year cycle cost. Should COI obtain adequate funding, it may then consider the cost, future cost risk and annual maintenance implications of the various lining and piping alternatives presented and make a decision as to seepage mitigation approach. It may then also decide as to its ability to self-perform any or all of the work or to contract out for part or all of the construction services. Detailed design survey, geotechnical support, detailed design, bidding, and construction could then follow. For a comprehensive project, the Board of Directors of COI has requested additional evaluation of this potential project; in particular, to assess if specific elements of the project may be viable given higher proportionate financial or operational benefits. It is anticipated that this additional analysis will be performed following completion of this COI water conservation and improvement evaluation.