Selecting the Best Pipeline Route Based on Facts Not Feelings

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Abstract
Design consultants and utility system owners must consider many factors during planning and design of linear pipeline projects. None is more important and typically more controversial than selection of the route for the pipeline.

This paper presents a case study of a route evaluation and selection process for a 78-inch diameter raw water pipeline near a major metropolitan area in central Texas. The approach used by the project team during preliminary design of the pipeline was developed to take feelings and interpretations out of the route selection process as much as possible. A decision analysis software program was used in evaluating four alternative pipeline routes, ranging in length from 28,000 feet to 42,000 feet. Portions of the alternative routes extended through environmentally-sensitive habitat, road right-of-way, state highway crossings, relatively narrow and congested construction corridors, a lake crossing, suburban neighborhoods and steep topography. These and other differences between the alternative routes made it necessary for the evaluation and selection process to be based on quantifiable criteria that could be readily defended instead of emotions and feelings of stakeholders, owners, and engineers involved.

The methodology used in identifying applicable evaluation criteria, establishing a quantitative rating system, and developing an unbiased ranking of the importance of each criterion will be discussed in this paper. Tabular and graphical presentations of data and numeric ranking scores will be included as examples to show how facts and not feelings should be used to select the best route for linear pipeline projects.

Introduction
Construction of both large and small pipelines is an absolute necessity in our world today to convey the required water, wastewater, storm water, and other flows that our communities depend on a day-to-day basis. Determining where those pipelines are located is many times a challenge because of balance that has to be obtained between competing impacts such as cost, schedule, difficulty of construction and permitting, impacts to people in the community, and impacts to the environment. The process of selecting the best pipeline route must answer questions such as:

- Does the route minimize adverse impacts to the environment?
- Will it result in the least possible impact to stakeholders?
- Is the selected route the most feasible and cost-effective?
- Can the required schedule be met?
- Are there any fatal flaws that could stop the project?

Very seldom will a single pipeline route answer all the above questions in a manner that is satisfactory to all who may have a stake in the project. Consequently, the route selection process cannot be solely based on feelings or opinions because these opinions will differ depending on the perspectives of the individuals offering them. Instead, as much as possible, the process must be based on quantitative or measurable data that does not vary with the perspective of the stakeholder.

Selecting a Pipeline Alignment Using Quantity Based Decision Analysis

In many cases, the significance of selecting the right pipeline route is minimized because it is simply viewed a step that an engineer or owner has to take so they can move on with detailed design and eventually construction. The result of this perspective is generally a minimal route evaluation effort which ultimately leads to either an incorrect decision or a decision that cannot be defended to Board members, council members, or most importantly to stakeholders affected by the alignment chosen. Typical mistakes that can be made if a logical, well thought out alternative route evaluation is not followed include:

- Clear criteria not being established in the beginning as a basis for selecting routes for detailed analysis.
- Subject matter experts and/or stakeholder representatives not being consulted in developing or the rating of the evaluation criteria.
- The rating/scoring system used is too loosely defined and left up to the feeling or opinion of whoever is doing the analysis. For example, my rating of a "3" and your rating of a "3" could be totally different.
- Stakeholders or representatives not being included in the rating or weighting process

Quantity based decision analysis avoids these mistakes by 1) gathering input from appropriate stakeholders (or stakeholders representatives) at the right times in the decision process and 2) using a quantity based scoring system rather than a feeling based rating system. As shown on Figure 1, this process does typically involve more steps and, more than likely, time to complete but the end result is a very defendable solution that truly considers all of the factors that come with constructing a pipeline, whether big or small.

Development of Screening Criteria to Determine Routes to be Evaluated in Detail

Identification of Routes for Detailed Evaluation

Determination of Goals and SubGoals for Selecting "BEST" Alignment
Determination of Measures to Determine How Well Goals Are Achieved

Quantify Measure Values
(i.e. cost, no. of homes impacted, linear feet of traffic lanes impacted)

Input Measure Values Into Decision Analysis Model and Convert To Utility Values (from 0 to 1)

Adjust Utility Values and Set Weighting For Different Preference Sets
(i.e. community, environmental, engineers, etc.)

Develop Weighting for Combined Preference Set

Analyze Results for Combined and Separate Preference Sets

Make Selection of "Best" Route

Field Verify Desktop Assumptions

Figure 1 – Pipeline Route Selection Using Quantity Based Decision Analysis

The following sections provide details of how a quantity-based decision analysis process was used in the route evaluation and selection process for a 78-inch diameter raw water pipeline near a major metropolitan area. The pipeline will feed the cities of Cedar Park, Leander and Round Rock's proposed 142 MGD regional water system from Lake Travis. These are three of the fastest growing cities in Williamson County, Texas and this proposed infrastructure will meet their needs for the next 50 years.

The approach used by the project team during preliminary design of the pipeline was developed to take feelings and interpretations out of the route selection process as much as possible. A decision analysis software program was used in evaluating four alternative pipeline routes, ranging in length from 28,000 feet to 42,000 feet. Portions of the alternative routes extended through environmentally-sensitive habitat, road right-of-way, state highway crossings, relatively narrow and congested construction corridors, a lake crossing, suburban neighborhoods and steep topography. These and other differences between the alternative routes made it necessary for the evaluation and selection process to be based on quantifiable criteria that could be readily defended.

Case Study - Brushy Creek Regional Utility Authority Raw Water Pipeline

The neighboring cities of Cedar Park, Leander and Round Rock are located approximately 16 miles northwest of downtown Austin, Texas. As Austin has grown, populations of the three suburban cities have increased dramatically in recent years. Studies to determine how to best meet the resulting increased water needs go back more than a decade.

Lake Travis is a reservoir on the Colorado River northwest of Austin, which was formed in 1942 by the Lower Colorado River Authority (LCRA) for flood control, water supply, electrical power generation and recreation. The City of Cedar Park operates a 23 MGD water treatment plant on the southern shore of the Sandy Creek arm of Lake Travis. LCRA also operates the 12 MGD Sandy Creek Water Treatment Plant on the northern side of the Sandy Creek arm, which currently supplies all of Leander's water needs. The two existing treatment plants had either reached their maximum capacities or were projected to do so by Year 2010. The City of Round Rock, which takes its water from a different surface water supply, also projected that its water treatment capacity would be exceeded as early as 2014.

Previous studies conducted by the cities showed that the most cost-effective way to access additional water from Lake Travis was to partner in a regional water supply and treatment system. In 2006, the three cities agreed to form a local government corporation called the Brushy Creek Regional Utility Authority (BCRUA). In order to balance cost impacts and water demands of the participating cities, BCRUA planned the regional facilities to be constructed in phases. Initial Phase 1 and ultimate treatment capacities will be approximately 30 MGD and 106 MGD, respectively. Phase 1 of the raw water pipeline will connect a new raw water intake and pump station, located adjacent to Cedar Park's existing treatment plant, to the new regional water treatment plant approximately 5.5 miles away.

Screening Criteria for Routes to be Evaluated in Detail

As with any pipeline route study, the number of possible alignments between the starting and ending points are almost unlimited. However, it is prudent to limit the number of alternatives by establishing some basic screening criteria that help rule out certain routes as being not feasible and therefore, should not be evaluated in detail. In the case of BCRUA's raw water pipeline, the screening criteria included:

- Capital Cost Upper Limit – Any alternative alignment involving significant lengths of underwater and/or tunnel construction was not considered to be financially feasible.
- Total Length of Pipeline – The straight line distance was approximately 24,000 feet, and any alternative alignment with a total length of more than twice that distance was also not considered to be financially feasible.
- Fatal Flaw Environmental Impact – A large environmental preserve, known as the Balcones Canyonlands Preserve (BCP), exists in the undeveloped area shown on the map on Figure 2. In this case, any alternative

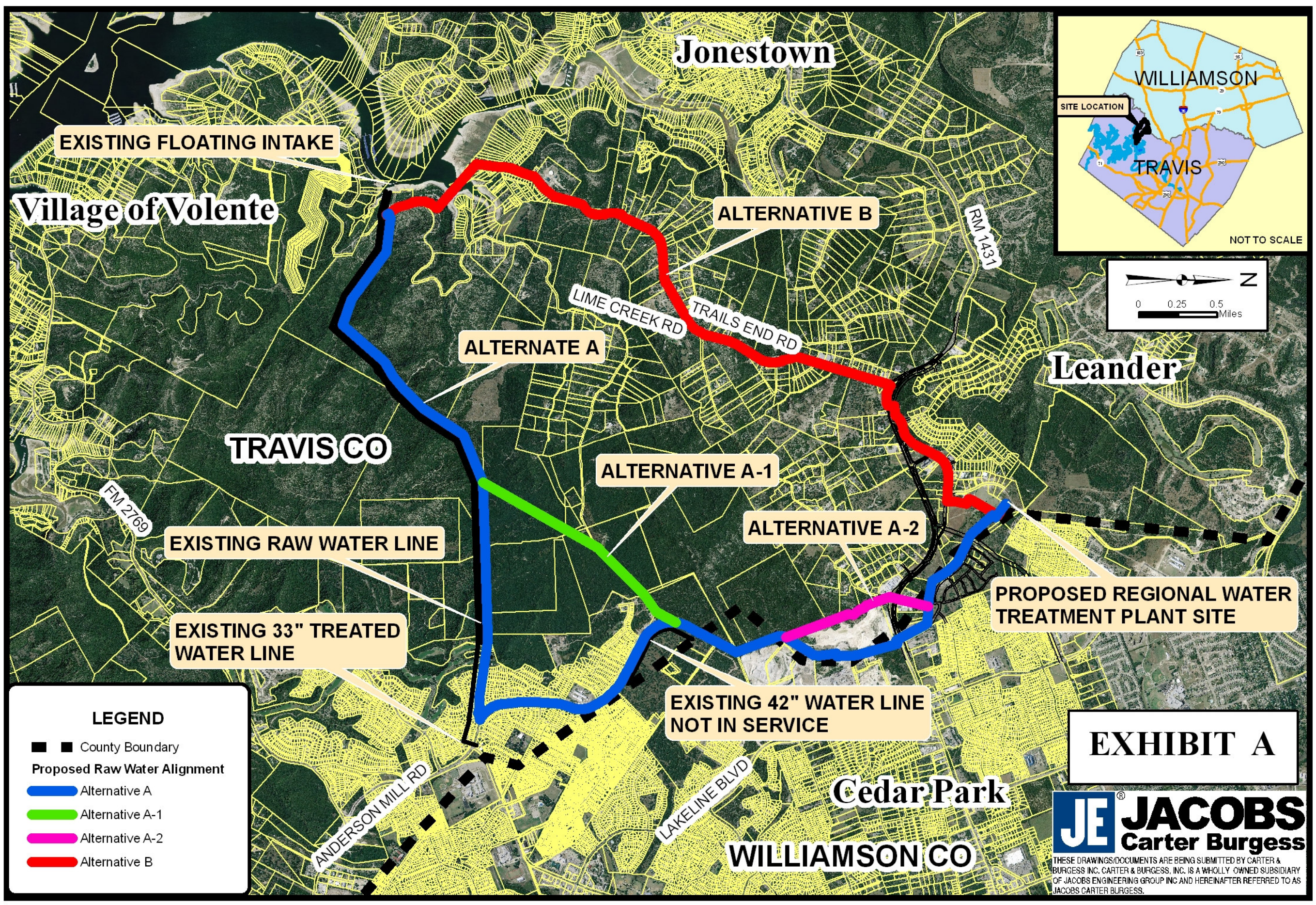
alignment that included crossing previously undisturbed BCP land with open cut construction methods was not considered to be feasible.

- Property Boundary Constraints – To encumber a large suburban tract with a pipeline easement that bisects the property would result in an extremely negative impact to the owner. Consequently, any alternative alignment that generally extended across the middle of a large tract of land was not considered to be feasible.

The screening criteria used to limit the number of alternative alignments to be evaluated will differ, depending on the unique locale of the particular pipeline. However, such a screening process is an important first step in selecting a pipeline alignment using a quantity based decision analysis.

Identification of Routes to be Evaluated in Detail

Based on this initial screening, the four alternative raw water pipeline alignments shown in Figure 2 and described below were identified for detailed evaluation:



Alternative No.	Description
A	Generally follows the route of an existing 36-inch treated water transmission pipeline and existing road right-of-way.
A-1	This variation of Alternative A included a deep tunnel under BCP land.
A-2	Another variation of Alternative A included an alignment along the west side of a limestone quarry.
B	Followed previously disturbed road rights-of-way for the majority of the distance but also required construction within a public park and deep tunnel under the L. Travis.

The process of identifying alternative alignments will typically raise certain project-specific key issues right away that are associated with each alternative. Some of the key issues associated with the four alternatives for BCRUA's pipeline included:

- Cost impacts for different construction methods. For example, even though the overall length of Alternative A-1 is approximately 4,000 linear feet shorter than Alternative A, its construction cost was $10 million more than Alternative A due to the cost of tunneling under BCP land.
- Advantages and disadvantages of utilizing previously disturbed corridors. Existing corridors minimize the overall footprint of the impact but they also create challenges with existing utilities, traffic, etc.
- The number of easements required. The time frame for acquiring easements was a critical consideration to meeting the project schedule. The more easements, the higher risk for delays.
- Extent of environmental impact. The existence of a relatively large environmental preserve within the corridor of alternative alignments was likely to have a major impact on selection of the preferred route.

Determination of Goals and Measures

After the alternative alignments were been identified, they were evaluated in detail and compared to each other in a logical fashion to ultimately select the preferred pipeline alignment. For this project team jointly developed four primary GOALS for selection of the final pipeline route:

1. <u>Lowest Cost</u> - Costs of the pipeline, habitat mitigation costs, easements, and permitting.
2. <u>Least Construction Issues</u> - Duration of construction, number of homeowners directly impacted, number of businesses and schools impacted, traffic impacted (length of lane closures required), construction risk quantified by length of construction under pavement and construction by tunneling.
3. <u>Least Environmental Impact</u> - Total acreage of disturbance, lineal footage of steep pipeline construction, acreage of Golden-Cheeked Warbler habitat disturbance, number of stream crossings, acreage pipeline through mapped karst features, and other associated environmental impacts.
4. <u>Least Permits and Easements</u> – Number of federal permits such as USACE and USFW, number of local jurisdictional permits, and number of permanent, temporary, and subsurface easements.

To determine the ability that each of these sites is able to achieve these primary GOALS relative to each other, the project team developed and quantified over 30 detailed MEASURES. The final GOALS and MEASURES used in the decision analysis process are shown in Appendix A. The GOALS, MEASURES, and the associated weighting was established through a series of meetings with the project team made up of the consulting engineers and staff from each of the three cities.

Developing Measure Values and Utility Scores

After the goals and measures were established, the values for these measures were developed and converted to a utility score based a predetermined scale which was usually the minimum and maximum values of the measures. The utility score is simply a measure of desirability between 0 and 1, with 1 being the most desirable and 0 being the least preferred value. The utility score is a common scale that is applied to all the values that allows for all measures to be compared to each other.

The example below shows the utility function for Construction Cost based on a straight line analysis. The figure shows that the utility is linearly dependent upon the construction cost over a specified range. For the Construction Cost analysis, the range is as follows:

- The lowest cost ($37,965,000) is set as the maximum utility score of 1.0.
- 140% of the lowest cost is set as the minimum utility score of 0.0.

All other measures were scored based on the actual minimum and maximum values observed for each measure.

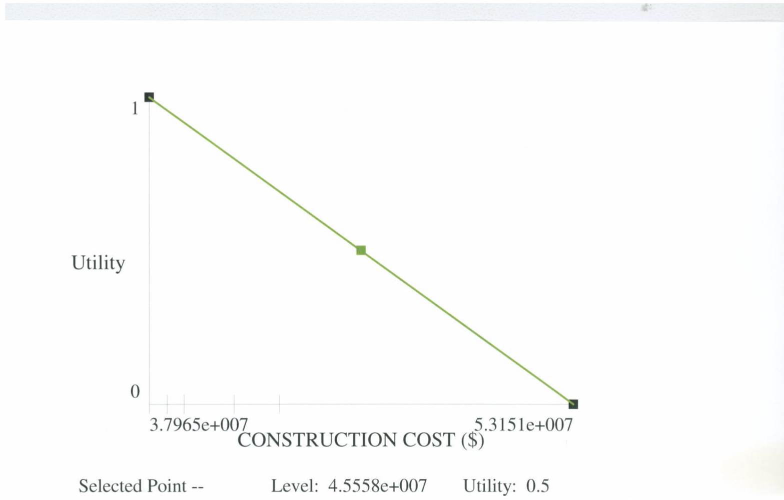


Figure 3 – Single Measure Utility Function of Construction Cost for Segments 5 Analysis

Weighting of Goals/Measures and Preference Sets

The Logical Decisions program allows evaluation scenarios (known as preference sets) to be developed by assigning weight factors to the measures and goals. Many different preference sets can be developed based on the different perspectives that stakeholders depending on what is most important to them. For example, owners of endangered species habitat preserve land will almost certainly weight environmental impacts the highest. This perspective would be represented with an environmental preference set. On the other hand, property owners whose driveways or improved property would be affected would rate construction issues very high. This perspective could be captured as a community impact preference set. Each of these different preference sets results in a different overall utility score for each alternative and potentially a different preferred alternative depending on the sensitivity of the model.

For BCRUA's raw water pipeline, the initial scenario that was evaluated assigned equal 25% weighting to each of the four goals. As shown in Table 1, Alternative B had the highest utility score using an equal weighting scenario. However, the scores for Alternatives A and A-2 were both within 10% of the highest score.

TABLE 1: ALTERNATIVE EVALUATION – UTILITY SCORES

GOAL	WEIGHT	UTILITY SCORE			
		A	A-1	A-2	B
CAPITAL COST	25%	1.000	0.335	0.820	0.961
CONSTRUCTION ISSUES	25%	0.740	0.350	0.938	0.268
ENVIRONMENTAL ISSUES	25%	0.097	0.434	0.023	0.787
PERMITTING & EASEMENTS	25%	0.593	0.484	0.625	0.625
AVERAGE		**0.607**	**0.401**	**0.602**	**0.660**

Sensitivity Analysis

In order to determine the sensitivity of the model, additional preference sets were developed by assigning different weighting to each goal. The additional scenarios assigned lower weights to the permitting and easement goal, based on the assumption that permitting and easement considerations are relatively equal and consequently are of less overall importance than other major goals. Table 2 shows five additional preference sets that were considered in BCRUA's route study.

TABLE 2: SENSITIVITY ANALYSIS WEIGHTING SCENARIOS				
SCENARIO	WEIGHT			
	CAPITAL COST	CONSTRUCTION ISSUES	ENVIRONMENTAL IMPACT	PERMITTING AND EASEMENTS
1	25%	25%	25%	25%
2	30%	20%	30%	20%
3	40%	10%	40%	10%
4	40%	30%	20%	10%
5	36%	27%	27%	9%
6	40%	20%	30%	10%

Final Selection of Route

The results of the sensitivity analysis are graphically shown in Figure 4. Based on these additional evaluation scenarios, the following conclusions were made:

- Alternative A-1 had the lowest utility score in all scenarios.
- Alternatives A and B had higher utility scores than Alternative A-2 in all scenarios.
- Alternative B had the highest utility score in all scenarios, except Scenario 4.
- Alternative A had the highest utility score in Scenario 4.

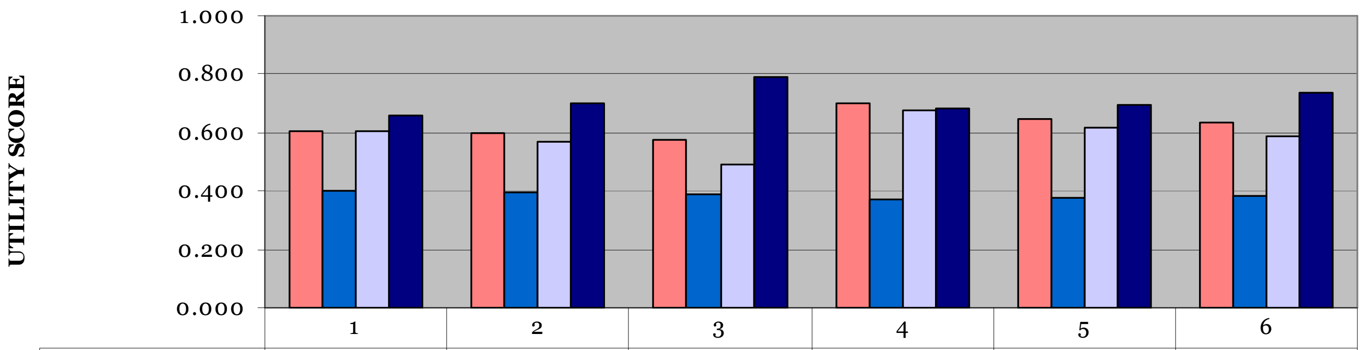
When the various preference sets (weighting scenarios) produce mixed results, it is necessary to look closely at the project-specific factors that contributed to those results. In the case of BCRUA's route study, capital cost was assigned a 40% weight in Scenario 4, which is a higher weight than the other three goals. However, the difference in total capital cost between Alternatives A and B was considered negligible at this level of evaluation. Consequently, the fact that Scenario 4 assigned the highest weight to capital cost resulted in an exaggeration of the cost difference between Alternatives A and B, and Alternative A was given the higher utility score. In addition, Scenario 4 assigned a lower weight (20%) to environmental impacts, which also resulted in a lower utility score for Alternative B.

Because the alternative scoring was so close between Alternatives A & B, additional investigation was performed to determine exactly how the environmental issues could impact the schedule and/or cost of the project for each of these alternatives. Through discussions with the U.S. Fish & Wildlife and some members of the BCP, it was determined that Alternative A and A-1 had a high potential during construction of encountering karst features containing endangered species. If pursued, both Alternatives A and A-1 would pose significant potential for schedule delays and increased construction costs due to additional permitting requirements and mitigation requirements, respectively. The same environmental evaluation was performed on Alternative B and it was determined that no significant environmental impacts existing along this route. As a result, Alternative B was selected as the recommended route for the raw water pipeline.

Conclusion

Design consultants and utility system owners must consider many factors during planning and design of linear pipeline projects. None is more important and typically more controversial than selection of the route for the pipeline because of the feelings and emotions that can enter into picture when people's lives are disrupted by any number of impacts that can occur in a pipeline project. This is why it is so important for the evaluation and selection process for a pipeline alignment to be based on quantifiable criteria or measurable data that can be readily defended and does not vary with the perspective of the stakeholder. A quantity-based decision analysis process, utilizing decision analysis software and a stakeholder input at key stages, can do just this by providing a logical approach to assimilating data associated with competing impacts in such a way that ultimately best achieves the combination of goals established for selection of the alignment.

FIGURE 4
UTILITY SCORES PHASE 1
BCRUA ROUTE STUDY



	1	2	3	4	5	6
ALIGNMENT A	0.607	0.596	0.572	0.701	0.646	0.636
ALIGNMENT A-1	0.401	0.397	0.391	0.374	0.380	0.383
ALIGNMENT A-2	0.602	0.566	0.494	0.677	0.617	0.585
ALIGNMENT B	0.660	0.703	0.788	0.685	0.694	0.737

SCENARIO

ALIGNMENT A ALIGNMENT A-1 ALIGNMENT A-2 ALIGNMENT B

APPENDIX A

BCRUA Goals & Measure Values

Preference Set **Balanced**

WEIGHT	GOAL / SUBGOAL / MEASURE	UNIT OF MEASURE	Measure Value			
			Alt. A	Alt. A-1	Alt. A-2	Alt. B
25%	**LOWEST CAPITAL COST**					
	CONSTRUCTION COST + EASEMENT COST + HABITAT MITIGATION COST + VALUE OF 4,200 LF OF EXISTING 42" PIPELINE IN ANDERSON MILL ROAD	$	$36,732,000	$46,507,000	$39,371,000	$37,311,000
25%	**LEAST CONSTRUCTION ISSUES**					
	DURATION OF CONSTRUCTION	# OF MONTHS	20	25	18	20
	HOMEOWNERS IMPACTED	# OF OWNERS	0	0	0	45
	BUSINESSES/SCHOOLS IMPACTED	# OF BUSINESSES	3	3	1	3
	TRAFFIC IMPACTED	L.F. OF LANE CLOSURE	5,100	650	5,100	20,330
	CONSTRUCTION RISK					
	CONSTRUCTION RISK - OPEN CUT IN EXISTING ROADWAY	LINEAR FEET	5,100	1,585	5,100	20,480
	CONSTRUCTION RISK - LONG TUNNEL CONSTRUCTION	LINEAR FEET	0	7,500	1,306	1,877
25%	**LEAST ENVIRONMENTAL IMPACT**					
	JURISDICTIONAL WATERS OF THE US	# OF CROSSINGS	2	0	2	1
	BCCP LANDS IMPACTED					
	BCCP LAND - DIRECT IMPACT (Clearing)	# OF ACRES IMPACTED	4.4	4.4	6.8	0
	BCCP LAND - INDIRECT IMPACT - TEMP CONSTN (Non-Clearing)	# OF ACRES IMPACTED	17	14.8	17	0
	BCCP LAND - INDIRECT IMPACT - TUNNELING (Non-Clearing)	# OF ACRES IMPACTED	6.0	8.6	6.0	0
	GOLDEN CHEEKED WARBLER HABITAT					
	GCW - DIRECT IMPACT ZONE 1 OR 2 (CLEARING)	# OF ACRES IMPACTED	12.4	12.4	30.3	117
	GCW - INDIRECT IMPACT ZONE 1 OR 2 (NO CLEARING - CONSTN W/IN 300' OF ZONE 1 OR 2)	# OF ACRES IMPACTED	277.9	177.6	277.9	16
	KARST ZONES					
	KARST ZONE 1	LF IMPACTED	12,300	9,530	11,194	0
	KARST ZONE 2	LF IMPACTED	19,090	16,400	19,920	10,596
25%	**LEAST PERMITTING AND EASEMENTS**					
	TXDOT/COUNTY ROW	# OF PERMITS REQ'D	2	3	2	2
	CORPS OF ENGINEERS PERMITS					
	INDIVIDUAL PERMITS	# OF PERMITS REQ'D	0	0	0	0
	NATIONWIDE PERMITS	# OF PERMITS REQ'D	1	1	1	1
	LCRA	# OF PERMITS REQ'D	1	1	1	2
	PERMANENT EASEMENT ACQUISITION	# OF EASEMENTS	13	13	13	5
	TEMPORARY EASEMENT ACQUISITION	# OF EASEMENTS	16	14	12	43

