



JOLLYVILLE TRANSMISSION MAIN

TECHNICAL MEMORANDUM NO. 11 EVALUATION OF ALTERNATIVE TUNNELING CONCEPTS

Water Treatment Plant #4 – Jollyville Transmission Main
Phase B – Final Design
CIP ID: 6935.016

B&V Project 167760
B&V File D-1.2

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From: Dennis Allen, P.E. – Project Manager, Black & Veatch
Date: September 22, 2010

Executive Summary

Black & Veatch completed an evaluation of alternative tunneling concepts to construct the Jollyville Transmission Main (JTM) subsequent to submittal of the draft Preliminary Engineering Report (PER) in November 2009 and the subsequent draft revised PER submitted in May 2010.

This memorandum summarizes five different tunneling alternatives. Four of these alternatives (Alternatives 1 through 4) use the recommended tunnel alignment in the PER and the fifth alternative (Alternative 5) proposes an all-tunneling alignment along the Pedernales Electric Cooperative (PEC), Anderson Mill Road and Pond Springs Road.

The significant differences among four tunneling alternatives along the PER-recommended alignment are the tunneling geology and hydrogeologic conditions (i.e., tunnel profile), location and purpose of shafts (in terms of working and tunnel boring machine retrieval shafts) and tunneling direction and slope from working shafts. The shaft location selection process and criteria were addressed in the draft Shaft Site Recommendation memorandum, dated June 24, 2010.

The tunneling alternatives evaluation is based on a review of available data to date and the following project parameters:

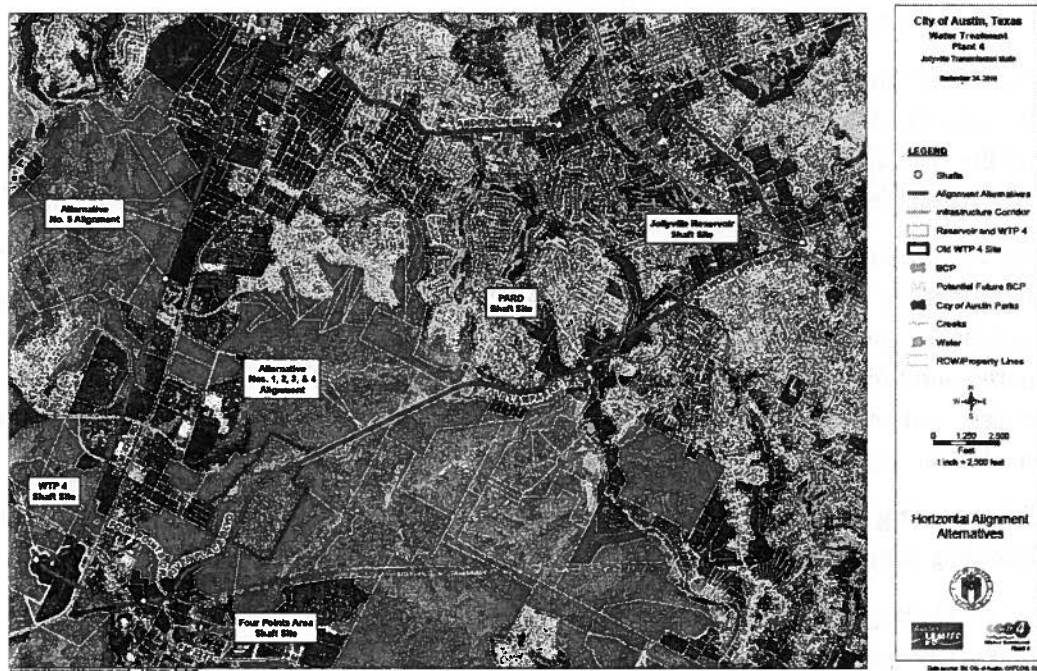
- Geologic and hydrogeologic conditions
- Comparable cost estimates
- Environmental impacts and permitting requirements
- Potential risks and constructability considerations
- Systems operations and maintenance and long-term reliability
- Construction impacts on community (traffic, noise, dust, safety, and other)

The City of Austin and Black & Veatch have taken into account input and comments from citizens, stakeholders, Environmental Commissioning Team, Austin Water Utility, Balcones

Canyonlands Conservation Plan (BCCP) Secretary, Construction Manager-at-Risk (CMAR) Team, and other interested and involved parties with the JTM project. Advantages and disadvantages of each tunneling alternative are presented in summary tables and further discussed in Sections 3 through 7 in this memorandum.

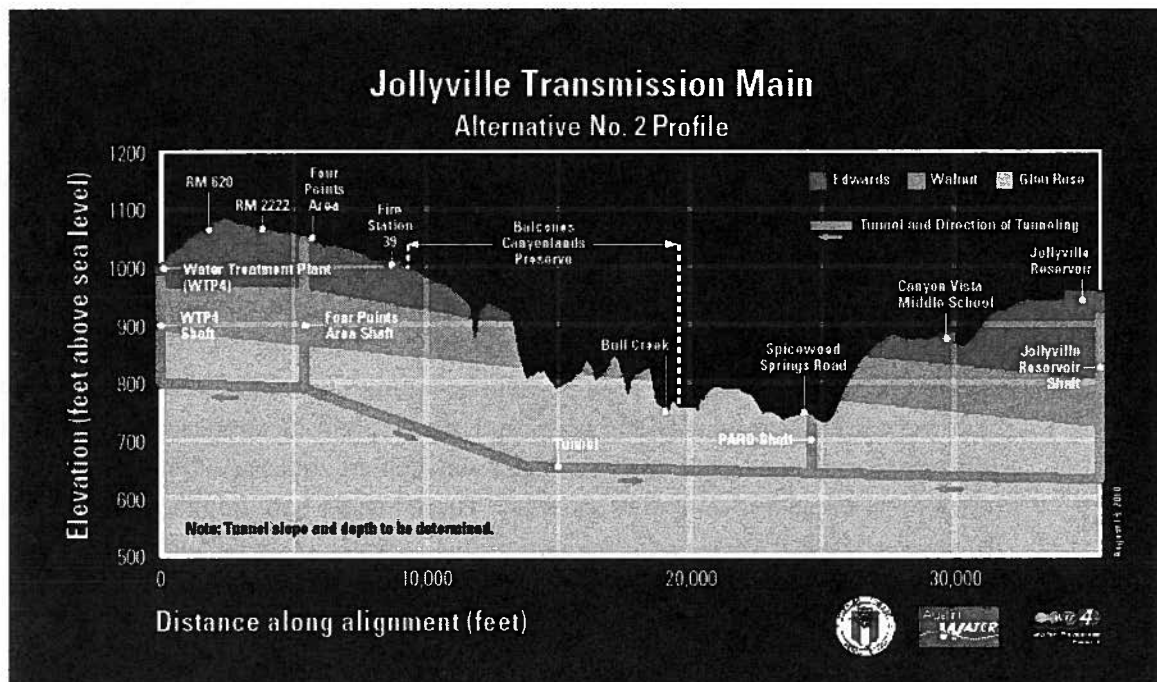
Recommended Tunneling Alternative

Black & Veatch recommends that tunneling Alternative 2 as described in this memorandum, be moved forward into the design phase. This alternative proposes to use the Four Points Area and Jollyville Reservoir sites for working shafts and WTP4 and Parks and Recreation Department (PARC) sites for tunnel boring machine retrieval shafts and pipe installation and grouting activities. The CMAR team indicated that the WTP4 site cannot be used as a working shaft due to facilities congestion and schedule conflicts with on-going and planned construction at this site. The conceptual horizontal alignment and profile of this alternative are shown in the figures below and in Attachments 2 and 3.



Horizontal Alignments for JTM - Tunneling Alternatives 1, 2, 3, and 4 follows the same alignment recommended in the PER. Alternative 5 follows the PEC corridor, Anderson Mill Rd., and Pond Springs Rd. route.

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Tunnel Profile for Recommended Alternative 2

From engineering design, operability, and future system reliability and maintenance perspectives, Alternative 2 allows the JTM to have a constant downslope toward Jollyville Reservoir, which will facilitate future inspection and maintenance of the pipeline. This alternative will enable drainage of the pipeline water into the reservoir from the deepest point in the pipeline, resulting in long-term efficiency, including savings of energy and labor.

Details and specifics of recommending Alternative 2 are included in Section 1.0 and benefits of moving Alternative 2 to design are as follows:

- a. Risk Management and Mitigation.* All tunneling will be driven in the Glen Rose limestone rock formation. Based on field data interpretation, there is a higher permeability zone in the upper portion of the Glen Rose formation near the eastern tunnel terminus or near the Jollyville Reservoir shaft. Alternative 2 proposes tunneling in less permeable zones below this portion. Selection of this alternative and a deeper working shaft at the Jollyville Reservoir also allows tunneling to be driven upslope, further reducing the risk of tunnel and TBM flooding, and associated costs with tunnel water removal during construction.

- b. Lesser Community Impacts.** The general land use is commercial and industrial where the working shafts at the Four Points Area and Jollyville Reservoir sites are located, thus will result in lesser residential impacts. Because of shorter construction duration and lesser activity (i.e., tunnel boring machine retrieval and pipe installation and backfill grouting only) at the PARD shaft site, there will be less truck traffic through residential streets and near school zones, and less noise and dust impacts.
- c. Constructability Considerations.** Tunneling with two TBMs from Jollyville Reservoir and Four Points Area sites, will have less probability of construction interferences and provides greater schedule certainty. It is anticipated that there will be fewer restrictions on working hours since these shaft locations are not immediately adjacent to residences and do not conflict with school zones or other traffic restrictions for access to major roadways. Tunnel water handling during construction (treatment and discharge) requirements at this location are expected to be less stringent and manageable compared to discharges to Bull Creek watershed at PARD shaft site.
- d. Operations.** No permanent air relief shafts are planned for the tunnel and therefore no high spots will be located between shafts. The tunnel will also drain by gravity to Jollyville Reservoir allowing efficient dewatering for maintenance access.
- e. Comparable Costs.** Based on comparable cost estimates of alternatives, this is a low-cost alternative considering both capital and long-term operating costs. This alternative would cost slightly higher than lowest cost alternative (Alternative 1) due to the need for deepening of the working shaft at Jollyville Reservoir. However, the long-term cost savings for operations and maintenance for tunnel dewatering and inspection activities, as well as potential mitigation of risks associated with tunnel water handling during construction makes this alternative a better solution for the City.

A comparative evaluation matrix summarizing five alternatives and the key evaluation criteria are presented in a table below. Additional supporting information is provided in the proceeding sections of this memorandum.

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JOLLYVILLE TRANSMISSION MAIN TUNNELING ALTERNATIVES EVALUATION MATRIX

Tunneling / Shaft Location Options	Comparative Costs (1)	Environmental Impacts	Tunneling Risks	Operability and Maintenance	Community Impacts	Other Remarks
Alternative 1	Lowest (\$90-\$100M)	Moderate	Moderate	Acceptable	High	PARD shaft is used for tunnel and pipeline construction
Alternative 2 *	Medium to Low (\$95-\$105M)	Moderate	Moderate to Low	Preferred	Moderate	PARD shaft is used for TBM retrievals and pipe installation and grouting
Alternative 3	Medium to Low (\$100-\$110M)	Moderate	Low	Not preferred	Moderate	PARD shaft used for TBM retrievals and pipe installation and grouting
Alternative 4	Medium to High (\$105-\$115M)	Moderate	High	Acceptable	Low	PARD shaft used for ventilation and grouting
Alternative 5 (PEC Route Alignment)	Highest (\$145-\$155M)	Moderate	Information not available	Not preferred	Moderate	Rejected. Does not meet budget / schedule and BCCP corridor permit criteria

* Recommended tunneling alternative

(1) Comparative cost estimate ranges are based on rough order of magnitude estimates for linear unit prices of tunnel and shaft construction.



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Black & Veatch recommends that Alternative 2, as described in this memorandum, be moved forward into the design phase. It is also noted that Alternative 5, the route along the PEC easement, Anderson Mill Road, and Pond Springs Road, is not recommended due to excessive costs beyond the City's project budget as well as exceeding design and construction schedule beyond project parameters.

Black & Veatch is prepared to develop the Draft Basis of Design Report based on Alternative 2 as presented in this memorandum. Following the City's approval of the final tunneling alternative, Black & Veatch will update the Basis of Design Report and finalize the contract documents, including the plans and specifications, and Geotechnical Baseline Report, and Geotechnical Data Report for bidding of the project.



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Section 1.0 Introduction

Black & Veatch completed an evaluation of alternative tunneling concepts to construct the Jollyville Transmission Main (JTM) subsequent to submittal of the draft Preliminary Engineering Report (PER) in November 2009. This memorandum summarizes five different tunneling alternatives. Four of these alternatives (Alternatives 1 through 4) use the recommended tunnel alignment in the PER, and the fifth alternative (or Alternative 5) proposes an all-tunneling alignment along the Pedernales Electric Cooperative (PEC) easement, Anderson Mill Road and Pond Springs Road.

The significant differences among the four tunneling alternatives along the PER-recommended alignment result from tunneling geology and hydrogeologic conditions (i.e., tunnel profile), location and purpose of shafts (in terms of working and tunnel boring machine retrieval shafts) and tunneling direction and slope from working shafts. The shaft location selection process and criteria were addressed in the draft Shaft Site Recommendation Memorandum, dated June 24, 2010.

The tunneling alternatives evaluation is based on a review of available data to-date and the following project parameters:

- Geologic and hydrogeologic conditions
- Comparable cost estimates
- Environmental impacts and permitting requirements
- Potential risks and constructability considerations
- Systems operations and maintenance and long-term reliability
- Construction impacts on community (traffic, noise, dust, safety, and other)

The City and Black & Veatch have taken into account input and comments from citizens, stakeholders, Environmental Commissioning Team, Austin Water Utility, BCCP Secretary, Construction Manager-at-Risk (CMAR) Team, and other interested and involved parties with the JTM project. Overall advantages and disadvantages of tunneling alternatives are summarized for each alternative is further discussed in Sections 3 through 7 in this memorandum.

This TM presents advantages and disadvantages for each alternative and comparative costs using rough order of magnitude estimates for unit prices for linear shaft and tunnel construction as shown. The cost estimates presented in each of the alternatives' evaluation are not official "opinions of costs." The unit costs can be assumed to be within planning

level estimates for each of the facilities and used as a means to determine relative impacts of the differences between each alternative as shown in Attachment 1.

While Alternatives 1 through 5 can all be designed and constructed to meet water transmission needs, Alternative 2 is recommended because it meets geology, hydrogeology, engineering, risk management, environmental and community impacts, cost, schedule, and system constructability and operations objectives and considerations (in no specific order) for the project listed below:

DESIGN OBJECTIVES AND SPECIFICS OF ALTERNATIVE 2

No.	Objectives	Specifics of Alternative 2
1.	Cost	Estimated to be within the City's project budget.
2.	Schedule	Construct within 30 months and commissioning in May 2014.
3.	Community Impacts	Reduced traffic impact on northeast residential areas by moving most of construction work from PARD site to Jollyville Reservoir.
4.	Environmental Impacts	No construction water discharges to Bull Creek and its tributaries by relocating working shaft to Jollyville Reservoir.
5.	Environmental Impacts	Engineers acknowledge presence of karst and other critical environmental features (CEFs) in the vicinity of the Four Points area shaft. The shaft design will accommodate mitigation, inspection, and contingency measures to minimize environmental impacts. It is not possible to meet the project schedule without the Four Points shaft.
6.	Geology & Geotechnical Design Risk Mitigation	Entire tunnel is in Glen Rose and avoids apparent high permeable zones (based on boring logs and testing) of Glen Rose by lowering tunnel invert at Jollyville Reservoir.
7.	Operations & Maintenance	No separate pumping and water removal for inspections and access for future O&M.

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No.	Objectives	Specifics of Alternative 2
8.	System Hydraulics	Profile will allow constant downward slope from WPT4 to Jollyville Reservoir, avoiding high-point bends (potential air pockets) in the pipeline.
9.	Working Hours	Fewer impacts of extended working hours near school zone or residential areas by reducing construction activities at the PARD site.
10.	Concurrence by Design and Construction Manager-at-Risk (CMAR) Team	Design and CMAR teams are in agreement that Alternative 2 balances constructability, operability, environmental and community impacts, and offers the best option to meet the cost and schedule objectives of the City.

Each of these items for Alternative 2 are further discussed in detail below with specifics in comparison to the other four alternatives or the Hybrid West-of-620 concept proposed by the community.

1. **Cost.** The cost Alternative 2 is estimated to be within the City's budgeted estimate of \$110 million. Horizontal tunnel alignment and JTM tunnel/pipeline length is 34,600 ft and is the same for Alternatives 1 through 4. Tunnel/pipeline length for the all-tunnel alignment along PEC corridor and Anderson Mill Road (or for Alternative 5), is about 48,200 ft or 30 percent longer. There will be additional costs for Alternative 5 (estimated to be in the order of \$50M) or approximately 50 percent over Alternative 2. Therefore, Alternative 5 is not recommended and has not been evaluated in further detail due to excessive costs beyond the City's budget estimate for the JTM. Alternatives 3 and 4 will also cost more than Alternative 2.
2. **Schedule.** Black & Veatch and CMAR Team are in concurrence that two tunnel boring machines (TBMs) are needed to meet 30-months construction schedule and to have the JTM in service by May 2014, and Alternative 2 is the best alternative to meet schedule objectives.

Based on critical path activities evaluation, (i.e., TBM acquisition, shaft excavation, TBM installation, mining out, TBM removal and repositioning, and pipe installation for different sections of the tunnel), there are potential schedule conflicts for Alternatives 1, 3, and 4, hence, meeting the required 30-month schedule requirement.

Two TBMs cannot be supported from the same working shaft site at the same time (as proposed in Alternative 1 at the PARD shaft site). Tunnel excavation and pipeline installation work must be done concurrently from multiple shafts, allowing the contractor to work from the Jollyville Reservoir and Four Points area shafts (i.e., Alternative 2, 3, and 4), concurrently. This provides an overall shorter schedule.

Alternative 3 will require up to 6 months longer construction schedule on critical path, simply because of 100 ft deeper shaft excavation at the Four Points area site.

Alternative 4 would require at least 4 extra months for dismantling and backing out of two TBMs and the pipeline installation work cannot start until the tunnel section from Four Points to Jollyville Reservoir has been fully mined out.

3. **Community Impacts.** There will be fewer community impacts by using PARD site shaft as a retrieval shaft as outlined for Alternatives 2, 3, and 4. This eliminates tunnel rock spoil removal from PARD shaft site and will reduce truck spoil traffic more than 90 percent. However, note that PARD shaft must be utilized for pipe installation and backfill grouting to meet the 30-month construction schedule.
4. **Environmental Impacts.** With highly pristine baseline water quality parameters and restrictions imposed on discharges to surface waters of Bull Creek, tunnel construction water handling (say, up to 300 gallons per minute) at PARD shaft site will be difficult and costly for Alternative 1. Alternatives 2, 3, and 4 provide a viable option of discharge to sanitary system nearby, and based on discussions with AWU, no significant upgrading of existing laterals leading to lift station will be necessary.
5. **Environmental Impacts.** Black & Veatch acknowledges the concerns regarding presence of and potential impacts to groundwater and Critical Environmental Features (CEFs) and the location of Four Points area shaft site upstream of Bull Creek headwaters. However, the CMAR team indicated that the WTP4 site cannot be used as a working shaft due to facilities congestion and schedule conflicts with the on-going and planned construction at this site. No other suitable shaft location

is identified or available other than the Four Points area site to use the permitted infrastructure route across the BCP. Furthermore, Black & Veatch agrees with the CMAR that a tunneling alternative without a shaft at the Four Points area site is not possible to design and construct the JTM on time. Therefore, it is Black & Veatch's opinion that given the tunnel access requirement, schedule and very likely for project budget requirements, it is not feasible to construct the tunnel without the Four Points area shaft. The final determination on Four Points shaft will be made pending the City and EC's review and decision.

The design, CMAR, and City project management teams will continue to work with the EC Team to address CEFs and to the extent possible, avoid, and minimize impacts to groundwater and all CEFs as a result of locating the construction shaft at the Four Points site. The design team also acknowledges that continuous monitoring and inspection by EC Team, a contingency plan, and perhaps, a contingency budget for unanticipated activities in the contract, can be included to mitigate any adverse impacts on CEFs.

Please also note that our team members Hicks Environmental and Zara Environmental have been assisting in the CEFs surveys within the footprint and perimeter of proposed shaft locations, including Four Points site. No significant finds were reported to date that can be deemed as "fatal flaw" toward protection of CEFs using appropriate mitigation, inspection, and contingency measures.

6. **Geology & Geotechnical Design Risk Mitigation.** All tunneling will be in Glen Rose Formation to mitigate impacts to karst features. Glen Rose is relatively impervious (less groundwater flow) for tunneling purposes; however, borings indicated some higher permeable zones near the northeast section. Borings JT-104, JT-124, JT-125 and JT-126 in this section have zones of permeability in the range of 2×10^{-4} to 2×10^{-3} cm/sec compared to less than 1×10^{-6} cm/sec for most other boreholes and sections tested. Alternative 2 effectively avoids the high permeability zones by deepening the tunnel in this section (or lowering tunnel invert) and reduces potential impacts and risks of dealing with this zone.
7. **Operations & Maintenance.** Long-term system operations and maintenance (O&M) costs will be less with Alternative 2 since the water in pipeline (about 10 million gallons) can be readily pumped out into the Jollyville Reservoir because it will be the deepest point in the system. This will also limit the service downtime for the pipeline for inspection and repair activities. Pipeline emptying will be necessary for a manned-access for future inspections and maintenance. Use of the PARD or Four Points area shafts will be prohibitive to discharge treated (i.e.,

chlorinated) water to surface waters to Bull Creek. The associated long-term cost savings for pipeline water handling (i.e., pumping, trucking, and disposal, etc.) can be as much as \$50K to \$100K for each inspection. This will be a repetitive cost over the service life of facility and can be significant depending on the need and frequency of inspections and maintenance.

8. **System Hydraulic Design.** A high-point bend in the pipeline may result in the pipeline under Alternative 3 vertical profile. This could cause air entrapment in the pipeline, and result air hammer effects or surges in the system during operations. While this can be mitigated with an air relief valve at PARD shaft, details are yet to be determined during final design, including hydraulics and surge analysis. It is a better design practice to avoid by adjusting vertical alignment accordingly.
9. **Working Hours.** Imposing limits on working hours can severely impact tunnel construction schedule. Tunnel mining typically occurs around the clock, say, two 10-hour or 12-hour shifts each day; one for TBM mining other for TBM maintenance and materials delivery and support. Alternative 2 will not likely be impacted by restrictions on working hours compared to Alternative 1 which uses the PARD shaft for removing excavated rock.
10. **Black & Veatch and CMAR teams** have discussed these five alternatives and based on overall project objectives, and specifically for cost, schedule, and constructability reasons, both teams concur that Alternative 2 should be advanced to design. Other alternatives can be identified, plausible, or may be preferred for different reasons or objectives, however, following uniformly applying the project constraints, alternative selection and recommendation criteria presented in the draft Preliminary Engineering Report and subsequent memoranda, and the specifics discussed above, it is Black & Veatch's opinion that Alternative 2 should be advanced to the design phase.

Section 2.0 Design Parameters and Requirements

This technical memorandum is based on using the tunnel alignment from WTP4 to the Jollyville Reservoir as presented in the draft Preliminary Engineering Report, dated November 2009. The scope of work, the City of Austin and CMAR also required Black & Veatch to use the following design parameters in the development of tunneling alternatives:

JTM DESIGN PARAMETERS AND REQUIREMENTS		
No.	Design Parameter	Description and Rationale
1.	Tunnel Horizontal Alignment	Follows the tunnel alignment as evaluated and recommended in the draft PER.
2.	Design and Bid Documents Schedule	Design and complete bid-ready contract documents by March 31, 2011 with an anticipated notice to proceed for construction in Fall 2011.
3.	Construction Schedule	The JTM construction must be finished by Spring 2014 when WTP4 is scheduled to be operational. This schedule only allows a total of 30 months for construction, requiring utilization of two tunnel boring machines (TBMs).
4.	Shafts Locations	Tunnel shafts may be located at WTP4, Four Points Area, PARD, and Jollyville Reservoir (JR) site as presented in the draft Shaft Site Recommendations memorandum.
5.	Minimal Environmental Impacts	No or minimal construction and operations impact objectives must be targeted for sensitive environments, including protected endangered or threatened species, karst impacts, and other critical groundwater and surface water resources.
6.	Working hours	Expanded working hours will be allowed. Tunnel rock hauling at PARD shaft site will be restricted to approximately 6 hours per day. Working hours and expanded hours must conform to City codes and ordinances.
7.	Truck loads	Contractors may use maximum capacity trucks as allowed by the road limits for tunnel rock removal and materials delivery.
8.	Project Budget	Construction costs must not exceed the City of Austin's project budget.

Additional Subsurface Data Gathering Activities

Geotechnical and hydrogeologic data gathering activities for the shaft sites and tunnel are on-going. Subsurface borings and data interpretation have not yet been completed at the Four Points Area site (JT-112), the JR site (JT-127), and three borings along River Place Boulevard (JT-113, -114, and -115). Detailed geotechnical information resulting from these

additional borings may influence the findings presented in this TM as well as the basis of design. Geotechnical data will be compiled in a comprehensive geotechnical data report.

Tunnel Horizontal Alignment and Shaft Locations

Tunnel horizontal alignments for Alternatives 1 through 4 are same as the recommended alignment in the PER. This alignment begins at WTP4 and proceeds east across RM 620; turns northeast crossing RM 2222; follows River Place Boulevard to the original WTP4 Bull Creek site; crosses under the Balcones Canyonlands Preserve (BCP) within the 10(a) permit infrastructure corridor; and follows Old Lampasas Trail and Spicewood Springs Road to the Jollyville Reservoir (see Attachment 2).

Subsequent to the submittal of the PER, the possible shaft locations have been re-evaluated in detail in the Draft Shaft Site Recommendation Memorandum, dated June 24, 2010. The design team has used three main criteria (environmental impact, community impact and constructability) and approximately 30 subcriteria for shaft location screening and selection process.

The City and Black & Veatch have also taken into account input and comments from citizens, stakeholders, Environmental Commissioning Team, Austin Water Utility, BCCP Secretary, CMAR Team, and other interested and involved parties with the JTM project for the recommendation of the shaft locations. As a result, the following four shaft sites are recommended for tunnel construction access, categorized either as working shaft (tunnel excavation, spoil removal, materials and equipment storage, etc.) or tunnel boring machine (TBM) retrieval shaft:

- WTP4 site (tunnel connection to treatment plant)
- Four Points Area site
- PARD site, and
- Jollyville Reservoir (JR) site (tunnel connection to Jollyville Reservoir)

A description of the five tunneling alternatives, including shaft locations and comparative costs are summarized below and further discussed in Sections 3 through 7 of this memorandum.

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DESCRIPTION OF TUNNELING ALTERNATIVES, SHAFT LOCATIONS AND COMPARATIVE COSTS *		
Alternative	Description and Shaft Locations	Cost Range * (\$ Millions)
Alternative 1	Horizontal alignment is same as the PER-recommended alignment. Tunnel will be approximately 34,600 feet long. Shafts are located at WTP4, Four Points Area, PARD site, and Jollyville Reservoir (JR). The PARD and Four Points Area sites are used as working shafts. All tunneling is upslope. Northeast end of tunnel is routed through the high permeability zone in Glen Rose.	\$90-\$100
Alternative 2 (recommended)	Horizontal alignment is same as the PER-recommended alignment. Tunnel will be approximately 34,600 ft long. Working shafts are located at Four Points Area and JR. The PARD and WTP4 sites are used for TBM retrieval. Increased depth of the JR shaft will facilitate tunneling upslope from JR to PARD site and put alignment below high permeable zone. Tunneling is down gradient from Four Points to PARD site. Tunneling up gradient from Four Points Area to WTP4.	\$95-\$105
Alternative 3	Horizontal alignment is same as the PER-recommended alignment. Tunnel will be approximately 34,600 feet long. Working shafts are located at Four Points Area and JR. The PARD and WTP4 sites are used for TBM retrieval. The increased depth of JR and Four Points shafts allows for all up gradient tunneling. Considerably deeper shaft is needed at Four Points Area site.	\$100-\$110
Alternative 4	Horizontal alignment is same as the PER-recommended alignment. Tunnel will be approximately 34,600 feet long. Working shafts are located at Four Points Area and JR. The PARD shaft will be used for ventilation and grouting only. No significant construction activity on Spicewood Springs Road and Old Lampasas Trail. Requires backing out of TBMs through the tunnel and creates high risk of tunneling without an access or retrieval shaft.	\$105-\$115
Alternative 5	Alternative 5 is all tunnel option routed along the PEC easement starting from WTP4 to AWU land on Anderson Mill Rd to Pond Springs Rd and finally to the JR site. Tunnel will be approximately 48,200 feet long. Due to environmental constraints and community/traffic impacts, entire route will have to be tunneled. Tunneling will be up gradient from JR to Anderson Mill, and up gradient from Anderson Mill Rd to WTP4. The cost and schedule of this alternative exceeds project criteria, therefore, not recommended.	\$145-\$155

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* A cost estimate range (low-high) is used to account for variables, including market conditions and prices of materials at the time of bidding, contract bonds, insurance, availability of skilled local labor and labor productivity factors, easement variations, power delivery to job site, miscellaneous contract requirements, and implementation of various environmental protection controls and risk management strategies.

Section 3.0 Tunneling Alternative 1

The horizontal alignment is same as the PER-recommended alignment, and begins at WTP4 and proceeds east across RM 620; turns northeast crossing RM 2222; follows River Place Boulevard to the original Bull Creek site; crosses under the BCP; and follows Old Lampasas Trail and Spicewood Springs Road to the Jollyville Reservoir (see Attachment 2).

Shafts are located at WTP4, Four Points Area, Parks and Recreation Department (PARD) site, and Jollyville Reservoir. The PARD and Four Points Area sites are used as working shafts. All tunneling is up gradient. The conceptual tunnel profile is shown on the figure entitled "Alternative 1" in Attachment 3.

This alternative is the lowest capital cost alternative using comparable costs. However, the deepest point in the tunnel will be at the PARD site and long-term operation and maintenance inspections may require dewatering from the PARD shaft site and installation of a permanent tunnel access and maintenance facilities at this location. Discharge of water to empty the tunnel for inspection will also be costly since it cannot readily be pumped to the Jollyville Reservoir.

The advantages and disadvantages of Alternative 1 are summarized below.

ALTERNATIVE 1	
Advantages	Disadvantages
Shortest tunnel option.	Working shaft at PARD site will increase traffic on Spicewood Springs Road, peaking to 25-35 truck loads (or 50-70 truck trips each way) per day during tunnel rock removal
Lowest construction cost.	PARD site requires a Chapter 26 Hearing.
Tunneling up gradient reduces TBM flooding risk & associated pumping costs.	Proximity of PARD shaft to a tributary of Bull Creek
Downstream of known Jollyville Plateau Salamander sites, outside of Karst Zones 1 and 2 (PARD site only).	Does not address potential risks with high rock permeability zones in Glen Rose near the JR site.
	Working hours will be restricted at PARD site, potentially impacting schedule and cost.
	Tunnel construction water treatment and discharge requirements can be extensive.
	Community concern over the impact of PARD shaft on community during construction.

Section 4.0 Tunneling Alternative No. 2

The horizontal alignment for Alternative 2 is also identical to the PER-recommended alignment (see Attachment 2). Four Points Area and Jollyville Reservoir sites shafts will be used for tunnel construction and PARD and WTP4 sites will be used for TBM retrieval. If available, WTP4 site may also be used for tunnel construction from WTP4 to Four Points Area site. Tunneling is up gradient from Four Points Area to WTP4 and tunneling is down gradient from Four Points Area to PARD site. The tunnel profile is depicted on the figure entitled "Alternative 2" in Attachment 3.

The increased depth of the JR shaft will facilitate tunneling upslope from JR to PARD site and also pipeline dewatering at the deepest point for future operation and maintenance purposes. Tunnel will be below the high permeability zone encountered at the northeast terminus of tunnel. The advantages and disadvantages of Alternative 2 are summarized below.

ALTERNATIVE 2 (recommended)	
Advantages	Disadvantages
Shortest tunnel option and second lowest tunnel costs (comparable costs).	Deeper JR shaft increases costs.
Geotechnical investigation near JR site revealed high rock permeability layers in the upper Glen Rose formation, which may require a deeper shaft at the JR site, but reduces tunneling risks for groundwater inflows.	Deeper tunnel from JR to PARD may increase pipe thickness and cost.
Low point at JR will facilitate future dewatering for operation and maintenance, and provide long-term efficiency and cost savings of energy and labor.	PARD site will be used for TBM retrieval, pipe laying and grouting, and requires Chapter 26 hearing.
No tunnel rock removal from PARD site. Will only remove PARD shaft rock resulting in greater than 90% reduction in rock hauling traffic compared to Alternative 1. Significant reduction in hauling on Spicewood Springs Road resulting in fewer community impacts at PARD shaft site.	Tunneling downslope from Four Points Area shaft to PARD shaft increases tunnel and TBM flooding risk and associated pumping costs during construction. Labor costs also increase while tunneling downslope.
Shortest construction schedule due to availability of extended working hours at non-PARD shaft locations.	Concern over the impact of PARD shaft on community during construction.
Tunnel construction water treatment and discharge requirements are less extensive at JR site.	

Section 5.0 Tunneling Alternative No. 3

Alternative 3's horizontal alignment is also identical to the PER-recommended alignment (Attachment 2). Four Points and Jollyville Reservoir sites shafts will be used for tunnel construction and PARD and WTP4 sites will be used for TBM retrieval. If available, WTP4 site may also be used for tunnel construction from WTP4 to Four Points site. The tunnel profile is depicted on figure titled "Alternative 3" in Attachment 3.

The increased depth of JR and Four Points Area shafts allows for all up gradient tunneling.

The advantages and disadvantages of Alternative 3 are summarized below.

ALTERNATIVE 3	
Advantages	Disadvantages
Shortest tunnel option.	Deeper Four Points Area and Jollyville shaft increases costs.
No tunnel rock removal from PARD site. Will only remove PARD shaft rock resulting in greater than 90% reduction in rock hauling traffic compare to Alternative 1. Significant reduction in hauling on Spicewood Springs Road resulting in fewer community impacts at PARD shaft site.	Deeper tunnel from Four Points Area to JR increases pipe thickness, cost, and increase overall construction schedule.
Tunneling upslope reduces TBM flooding risk and associated pumping costs.	Retrieval shaft required at PARD site requires a Chapter 26 hearing.
Shorter construction schedule than current proposed alignment due to availability of extended work hours at non-PARD shaft locations.	Concern over the impact of PARD shaft on community during construction.
Tunnel construction water treatment and discharge requirements are less extensive at JR site.	

Section 6.0 Tunneling Alternative No. 4

Alternative 4's horizontal alignment is also the same as the PER-recommended alignment (Attachment 2). Tunnel excavation will be from the Jollyville Reservoir and Four Points Area shafts. WTP4 site will be used TBM retrieval shaft. The tunnel profile is depicted on the attached figure titled "Alternative 4" in Attachment 3.

The PARD shaft is used for ventilation, grouting, and intermediate long-term O&M access between Four Points and Jollyville Reservoir. The TBMs must be backed out of working shafts.

The cutter wheels for the TBMs used for this alternative will have to be sacrificed (i.e., dismantled and cut up in smaller pieces in the tunnel) in order to allow the TBMs to be backed out and removed from the starting shafts. This will result in additional costs and likely construction schedule delays.

No significant construction activity on Spicewood Springs Road and Old Lampasas Trail except for ventilation, grouting, and future O&M access.

This alternative has high construction risks and potential for contract interferences, change orders and delays.

The advantages and disadvantages of Alternative 4 are summarized below.

ALTERNATIVE 4	
Advantages	Disadvantages
Shortest tunnel option.	Tunneling downslope from Four Points Area shaft increases TBM flooding risk & associated pumping costs. Alternatively, tunneling upslope will require deeper shafts at startup (Four Points Area or WTP4 sites).
No significant construction traffic on Spicewood Springs road (reduced by 95 percent compared to Alternative 1), and fewer community concerns about the PARD site shaft.	Specialized TBM with removable cutterwheel and ability to be backed out of tunnel may be required. Additional TBM water protection enclosures may also be necessary.
Low point at JR will facilitate future dewatering for operation and maintenance, and provide long-term efficiency and cost savings of energy and labor.	TBM demobilization is more complex and costly because TBM and trailing gear will need to be removed through thousands of feet of tunnel rather than simply hoisted out of a shaft.
Tunnel construction water treatment and discharge requirements are less extensive.	Deeper Jollyville Reservoir shaft increases cost.



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ALTERNATIVE 4	
Advantages	Disadvantages
	Deeper tunnel from JR to PARD increases pipe thickness and cost and extends schedule beyond project parameters.
	PARD site will require a Chapter 26 hearing.

Section 7.0 Tunneling Alternative No. 5 (PEC Easement Route)

Alternative 5 tunnel alignment is routed along Pedernales Electric Cooperative (PEC) easement from WTP4 to Austin Water Utility land on Anderson Mill Road. From that point, it is routed along Anderson Mill Road and Pond Springs Road to Jollyville Reservoir (Attachment 2). This alternative does not have trenching or open cut pipeline. The JTM pipe size needs to be increased to off-set added friction losses in the pipeline due to increased length relative to other alignments recommended in the PER.

The entire length of Alternative 5 alignment will need to be tunneled due to numerous environmental, easements, traffic, and utility conflicts and constraints associated with open cut construction as outlined below:

- Within the PEC easement from WTP4 to Anderson Mill Road, open cut construction is not feasible because the proposed route traverses protected cave buffers, the Balcones Canyonlands Preserve (which may require an amendment to the Section 10a Federal Permit), the headwaters of tributaries draining to known Jollyville Plateau Salamander habitat, known Black Capped Vireo and Golden Cheeked Warbler habitat, potential waters of the United States, requiring at a minimum a Nationwide Permit from the United States Corps of Engineers, existing developments, and roads.
- Along Anderson Mill Road from the PEC easement to Highway 183, a pipeline installed via open cut construction will not allow for gravity flow because the pipeline will be higher in elevation than the water levels in the finished water clear wells at WTP4. In addition, open-cut construction would significantly impact local businesses and residences.
- For the remainder of the proposed route – along Anderson Mill Road (5 lanes wide) from Hwy 183 to Pond Springs Road, and then along Pond Springs Road (2 lanes wide) to the Jollyville Reservoir – open cut construction will be very complicated or cost prohibitive due to existing utilities and infrastructure within the rights of way and/or under the pavements, and will have adverse impacts on residences, regional traffic, and businesses in the area due to lane and/or road closures.

No profile information on this alignment is presented as there is no geotechnical data available at this time. It is also anticipated that three intermediate working, TBM retrieval, and long-term access shafts will be required along this alternative as shown in Attachment 2.



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This alternative is not recommended due to excessive costs beyond project budget and it does not meet WTP4 schedule (design and construction) requirements.

The advantages and disadvantages of this alternative are presented below:

ALTERNATIVE 5	
Advantages	Disadvantages
Haul routes will be on major roadways.	Tunnel is significantly longer and associated costs exceed City's budget estimate.
Austin Water Utility-owned land near Anderson Mill Road is available for shaft site which will not require a Chapter 26 hearing.	Does not meet design and construction schedule. Completion of the transmission main by Spring 2014 will not be achieved, as design would take at least an additional year because additional data will be needed (geotechnical, environmental) and a community outreach process re-started to include a broader audience.
No shafts in the Bull Creek watershed.	Real estate acquisition of easements on 30-40 private parcels (assuming Anderson Mill ROW is utilized), causing significant delay and expense.
Tunneling up gradient reduces TBM flooding risk & associated pumping costs.	Known BCP-permitted caves on Purcell tract, eliminating possible shaft options on this site.
Tunnel construction water treatment and discharge requirements are less extensive.	Proposed line would traverse the headwaters of known JPS sites in tributaries feeding Lake Travis, making locating shafts in the AWU owned Alternate WTP4 site environmentally undesirable.
	Potential for similar or increased residential impacts relative to Alternative 1 depending on final shaft locations and haul routes. Up to four intermediate shafts may be required.
	This alternative may require Section 10A permit revisions for BCP utility corridors. Shaft locations may require Chapter 26 hearing.
	Additional governmental entities (i.e., Williamson County) involved with additional/different requirements.



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Section 8.0 Conclusions

The Jollyville Transmission Main tunnel can be constructed using any one of the five alternatives presented herein; however, based on project scope of work and an evaluation of advantages and disadvantages associated with each alternative, Black & Veatch recommends that tunneling Alternative 2, as described in this memorandum, be moved forward into the design phase.

The selection of a tunneling alternative is a critical step in tunnel design and we understand the importance to the City and all other stakeholders involved. The Black & Veatch design team have received and incorporated input and comments from the City of Austin staff, Austin Water Utilities and Environmental Commissioning teams, BCCP Secretary, CMAR Team, citizens, stakeholders, and other parties engaged with the JTM project for the tunneling alternative selection and approval.

Black & Veatch is prepared to develop the Draft Basis of Design Report based on Alternative 2 as presented in this memorandum. Following the City's approval of the tunneling alternative for the JTM, Black & Veatch will update the Basis of Design Report and finalize the contract documents, including plans and specifications, Geotechnical Baseline Report, and Geotechnical Data Report for bidding of the project.

It is also noted that, based on comparable cost estimates, the Alternative 5 tunnel route is likely to cost 40 percent or more than other alternatives and exceeds the City's budget for the JTM. This alternative will also not meet the design and construction schedule objectives and will require additional infrastructure permitting across the BCP.

Enclosures: Attachments 1 through 3.



TECHNICAL MEMORANDUM EVALUATION OF ALTERNATIVE TUNNELING CONCEPTS

LIST OF ATTACHMENTS

1. Comparative Cost Estimate Breakdowns for Tunneling Alternatives
2. Horizontal Alignment of Tunneling Alternatives
3. Vertical Profiles of Tunneling Alternatives:
 - Alternative 1
 - Alternative 2
 - Alternative 3
 - Alternative 4



JOLLYVILLE TRANSMISSION MAIN

ATTACHMENT 1

COMPARATIVE COST ESTIMATE BREAKDOWN FOR TUNNELING ALTERNATIVES



JOLLYVILLE TRANSMISSION MAIN

COMPARATIVE COST ESTIMATE BREAKDOWN FOR JTM TUNNELING ALTERNATIVES

ALTERNATIVE 1		
Item No.	Item Description	Cost (\$M)
1	Jollyville Reservoir (JR) Retrieval Shaft (250 ft x \$5.9K/ft *)	\$1.48
2	PARD Working Shaft (70 ft x \$6.5K/ft)	\$0.46
3	Four Points Area Working Shaft (260 ft x \$6.5K/ft)	\$1.69
4	WTP4 Retrieval Shaft (200 ft x \$5.9K/ft)	\$1.18
5	Tunnel, Pipe Installation & Grouting (34,600 ft x \$1.925K/ft)	\$66.61
6	Shaft Pipe Installation & Backfill (450 ft x \$5.5K/ft + 330 ft x \$1.6K/ft)	\$3.00
7	Access Structure (2 x \$50K/ea. + 2 x \$150K/ea.)	\$0.40
8	Surface Restoration	\$0.40
	Subtotal	\$75.22
	Contingency (25%)	\$18.81
	Cost Estimate Range**	\$90 - \$100

*Unit shaft sinking costs of \$5.9K/ft is used for estimating 20-ft dia. retrieval shaft.

** A cost estimate range (low-high) is used to account for variables, including market conditions and prices of materials at the time of bidding, contract bonds, insurance, availability of skilled local labor and labor productivity factors, easement variations, power delivery to job site, miscellaneous contract requirements, and implementation of various environmental protection controls and risk management strategies.

COMPARATIVE COST ESTIMATE BREAKDOWN FOR JTM TUNNELING ALTERNATIVES

ALTERNATIVE 2		
Item No.	Item Description	Cost (\$M)
1	JR Working Shaft (320 ft x \$6.5K/ft)	\$2.08
2	PARD Retrieval Shaft (70 ft x \$5.9K/ft)	\$0.41
3	Four Points Area Working Shaft (260 ft x \$6.5K/ft)	\$1.69
4	WTP4 Retrieval Shaft (200 ft x \$5.9K/ft)	\$1.18
5	Tunnel, Pipe Installation & Grouting (6,500 ft x \$1.925K/ft + 3,200 x \$2.125K/ft) *	\$19.31
6	Tunnel, Pipe Installation & Grouting (5,100 ft x \$1.925K/ft)	\$9.82
7	Tunnel, Pipe Installation & Grouting (19,800 ft x \$2.1175K/ft) *	\$41.93
8	Shaft Pipe Installation & Backfill (520 ft x \$5.5K/ft + 330 ft x \$1.6K/ft)	\$3.39
9	Access Structure (2 x \$50K/ea. + 2 x \$150K/ea.)	\$0.40
10	Surface Restoration	\$0.40
	Subtotal	\$80.61
	Contingency (25%)	\$20.15
	Cost Estimate Range**	\$95-\$105

* Pipe cost was increased by \$200/LF due to increased depth for 1/3 of tunnel (3,200ft) from JR to PARD due to possible increase in pipe thickness. Tunneling cost was increased by 10 percent due to tunneling down gradient from Four Points Area to PARD.



JOLLYVILLE TRANSMISSION MAIN

****** A cost estimate range (low-high) is used to account for variables, including market conditions and prices of materials at the time of bidding, contract bonds, insurance, availability of skilled local labor and labor productivity factors, easement variations, power delivery to job site, miscellaneous contract requirements, and implementation of various environmental protection controls and risk management strategies.

COMPARATIVE COST ESTIMATE BREAKDOWN FOR JTM TUNNELING ALTERNATIVES

ALTERNATIVE 3		
Item No.	Item Description	Cost (\$M)
1	JR Working Shaft (320 ft x \$6.5K/ft)	\$2.08
2	PARD Retrieval Shaft (70 ft x \$5.9K/ft)	\$0.41
3	Four Points Area Working Shaft (410 ft x \$6.5K/ft)	\$2.67
4	WTP4 Retrieval Shaft (200 ft x \$5.9K/ft)	\$1.18
5	Tunnel, Pipe Installation & Grouting (5,100 ft x \$1.925K/ft)	\$9.82
6	Tunnel, Pipe Installation & Grouting (29,500 ft x \$2.125K/ft)*	\$62.69
7	Shaft Pipe Installation & Backfill (430 ft x \$5.5K/ft + 480 ft x \$1.6K/ft)	\$3.13
8	Access Structure (2 x \$50K/ea. + 2 x \$150K/ea.)	\$0.40
9	Surface Restoration	\$0.40
10	Additional Geotechnical Work (Field Work Only)	\$0.20
	Subtotal	\$82.98
	Contingency (25%)	\$20.75
	Cost Estimate Range**	\$100-\$110

*Pipe cost was increased by \$200/LF due to increased depth from JR to Four Points Area.



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****** A cost estimate range (low-high) is used to account for variables, including market conditions and prices of materials at the time of bidding, contract bonds, insurance, availability of skilled local labor and labor productivity factors, easement variations, power delivery to job site, miscellaneous contract requirements, and implementation of various environmental protection controls and risk management strategies.



JOLLYVILLE TRANSMISSION MAIN

**COMPARATIVE COST ESTIMATE BREAKDOWN FOR
JTM TUNNELING ALTERNATIVES**

ALTERNATIVE 4		
Item No.	Item Description	Cost (\$M)
1	JV Working Shaft (320 ft x \$6.5K/ft)	\$2.08
2	Four Points Area Working Shaft (260 ft x \$6.5K/ft)	\$1.69
3	WTP4 Retrieval Shaft (200 ft x \$5.9K/ft)	\$1.18
4	Tunnel, Pipe Installation & Grouting (5,100 ft x \$1.925K/ft)	\$9.82
5	Tunnel, Pipe Installation & Grouting (19,800 ft x \$2.1675K/ft) *	\$42.92
6	Tunnel, Pipe Installation & Grouting (9,700 ft x \$2.175K/ft) *	\$21.10
7	Shaft Pipe Installation & Backfill (580 ft x \$5.5K/ft + 270 ft x \$1.6K/ft)	\$3.29
8	Access Structures (2 x \$50K/ea. + 2 x \$150K/ea.)	\$0.40
9	Surface Restoration	\$0.30
10	Small diameter vent & access shaft (70-ft x \$2K/ft) for future O&M on PARD site	\$0.14
11	Specialized TBM Cost	\$2.20
12	TBM demobilization from the tunnel	\$2.00
	Subtotal	\$87.12
	Contingency (25%)	\$21.78
	Cost Estimate Range**	\$105-\$115



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* Pipe cost was increased by \$200/LF due to increased depth from JR to PARD and grouting cost was increased by \$50/LF due to construction access difficulties. Tunneling cost from Four Points Area to PARD was increased by 10 percent due to tunneling down gradient and grouting cost was increased \$50/LF due to construction access difficulties.

** A cost estimate range (low-high) is used to account for variables, including market conditions and prices of materials at the time of bidding, contract bonds, insurance, availability of skilled local labor and labor productivity factors, easement variations, power delivery to job site, miscellaneous contract requirements, and implementation of various environmental protection controls and risk management strategies.



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**COMPARATIVE COST ESTIMATE BREAKDOWN FOR
JTM TUNNELING ALTERNATIVES**

ALTERNATIVE 5 (ANDERSON MILL ROAD)		
Item No.	Item Description	Cost(\$M)
1	JR Working Shaft (320 ft x \$6.5K/ft)	\$2.08
2	Anderson Mill Road Working Shaft (200 ft x \$6.5K/ft)	\$1.30
3	WTP4 Retrieval Shaft (200 ft x \$5.9K/ft)	\$1.18
4	Tunnel, Pipe Installation & Grouting (48,200 ft x \$1.955K/ft) *	\$94.23
5	Shaft Pipe Installation & Backfill (520 ft x \$5.5K/ft + 800 ft x \$1.6K/ft)	\$4.14
6	Access Structure (3 x \$50K/ea + 2 x \$150K/ea)	\$0.45
7	Two Intermediate Working/Retrieval Shafts on PEC and Anderson Mill segments (2 x 200 ft x \$6.5K/ft)	\$2.60
8	Surface Restoration	\$0.30
9	Additional Re-engineering Fees	\$5.50
	Subtotal	\$111.78
	Contingency (35%) **	\$39.12
	Cost Estimate Range***	\$145-\$155

* Increased pipe cost by \$30/LF to allow for 6-inch increase in diameter required to deliver equivalent flow to the current proposed alignment.

** 35 percent contingency is applied for unknown geotechnical conditions, utilities, ROW, and other preliminary engineering parameters that have not been reviewed or analyzed for this alternative.



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*** A cost estimate range (low-high) is used to account for variables, including market conditions and prices of materials at the time of bidding, contract bonds, insurance, availability of skilled local labor and labor productivity factors, easement variations, power delivery to job site, miscellaneous contract requirements, and implementation of various environmental protection controls and risk management strategies.



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ATTACHMENT 2

TUNNEL HORIZONTAL ALIGNMENT FOR ALTERNATIVES 1, 2, 3, 4, AND 5

LEGEND

- Shalls
- Alignment Alternatives
- Infrastructure Corridor
- Reservoir and WTP 4
- Old WTP 4 Site
- BCP
- Potential Future BCP
- City of Austin Parks
- Creeks
- Water
- ROW/Property Lines

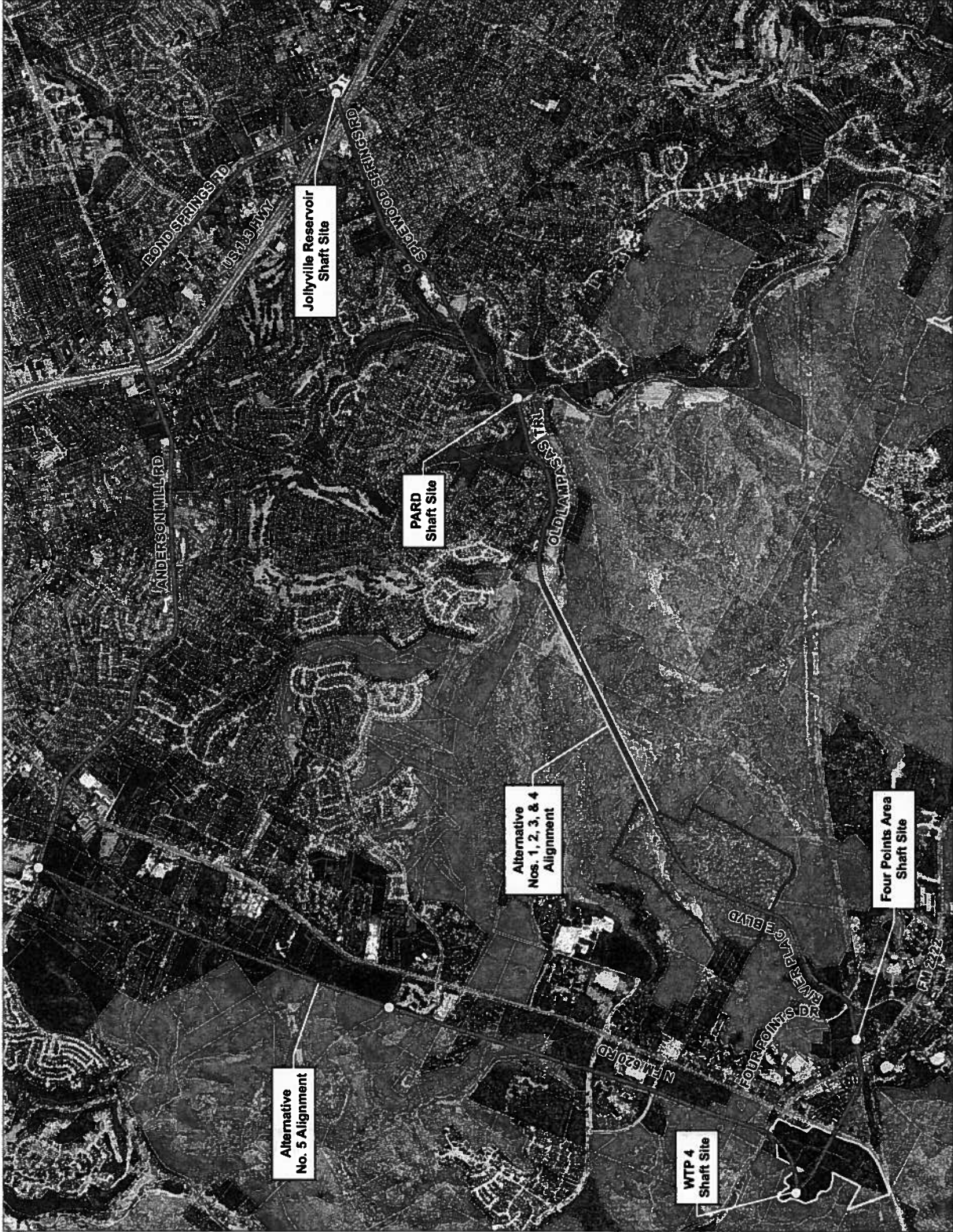


0 1,250 2,500
Feet
1 inch = 2,500 feet

Horizontal Alignment Alternatives



Data source: SW, City of Austin, CAPCOG, ESRI



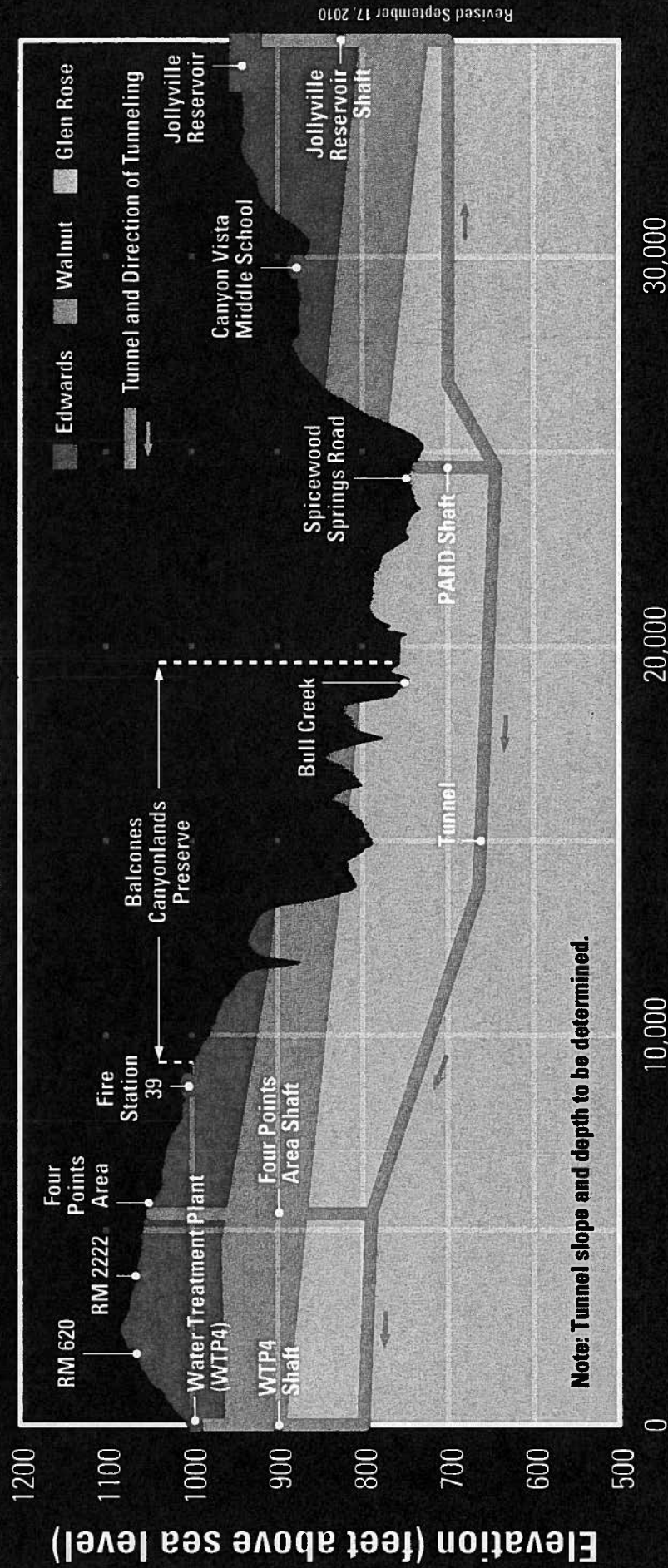


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ATTACHMENT 3

CONCEPTUAL TUNNEL PROFILES FOR ALTERNATIVES 1, 2, 3, AND 4

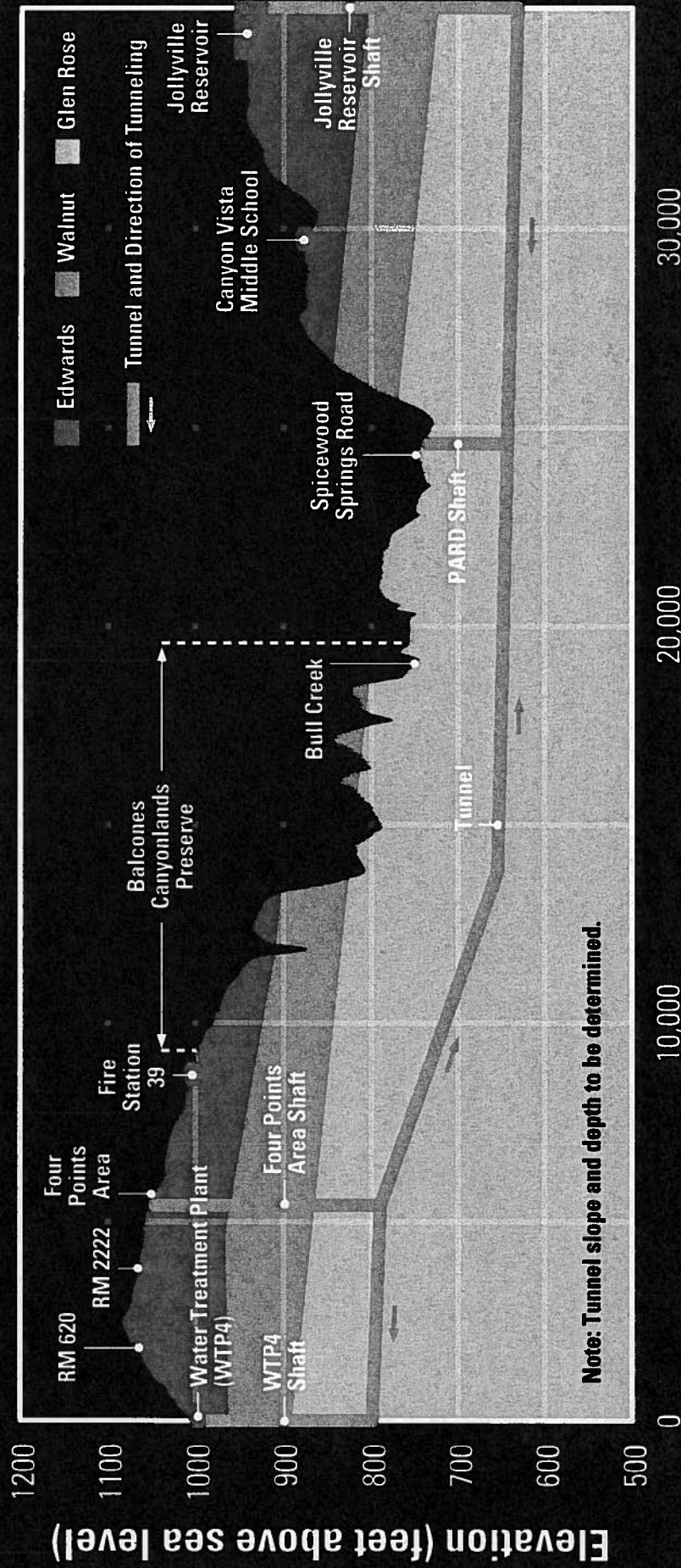
Jollyville Transmission Main Alternative No. 1 Profile



Revised September 17, 2010



Jollyville Transmission Main Alternative No. 2 Profile



Distance along alignment (feet)

