BLACK & VEATCH CORPORATION

MEMORANDUM

City of Pueblo, Colorado
Ammonia and Nutrient Removal Project
Green Reserve Business Case Evaluation

B&V Project 165157.0413
B&V File 30.0000
October 21, 2010

To: Mike Beck and Elizabeth Pine, CDPHE

From: Mark J. Maxwell, Black & Veatch

As discussed with you and Gene Michael, Wastewater Director for the City of Pueblo, Black & Veatch (B&V) prepared this business case evaluation (BCE) for Green Project Reserve (GPR) funding for the following elements of the current Ammonia and Nutrient Removal Project at the James R. DiIorio Water Reclamation Facility (i.e. Pueblo WRF):

- Replacement of less efficient constant-speed, multi-stage centrifugal blowers with new, high efficiency single-stage high-speed turbine (HST) units equipped with variable frequency drives (VFDs).

- Addition of first-stage denitrification facilities ahead of the oxic basins (i.e. pre-denitrification) to recover both energy and alkalinity through the oxidation of soluble biochemical oxygen demand (soluble BOD) and the reduction of nitrate to nitrogen gas.

This BCE was prepared in accordance with Attachment 2 to the document entitled *Procedures for Implementing Certain Provisions of EPA's Fiscal Year 2010 Appropriation Affecting the Clean Water and Drinking Water State Revolving Fund Programs*, dated April 21, 2010. Specifically, the GPR funding designation is being sought for both of the above-note energy conservation initiatives based on Section 3.0 of Attachment 2, Energy Efficiency. Projected energy savings will be quantified to determine if the categorical criteria are met (20 percent reduction in energy consumption) or if the BCE demonstrates the payback period of the proposed improvements is less than the useful life of the facilities.

For reference, the Pueblo WRF has a maximum month design capacity for 147,000 people, 19 million gallons per day (mgd) of flow, and 34,910 pounds per day (ppd) of total BOD. The WRF is currently being upgraded to meet more stringent effluent ammonia requirements for discharge to the Arkansas River. To biologically nitrify ammonia to nitrate, the WRF upgrade includes conversion from a trickling filter/solids contact (TF/SC) process to an all-activated sludge mode of treatment. In anticipation of Colorado's recently proposed nutrient quality rule, the City elected to install biological phosphorous (Bio-P) removal and first-stage nitrate removal (or pre-denitrification) facilities as part of the current project. This will pre-position the City to more cost-effectively comply with total phosphorous (TP) and total nitrogen (TN) limitations if/when they are promulgated by the Colorado Water Quality Control Commission

(WQCC). It is expected that promulgation of a nutrient quality rule may occur at a WQCC Hearing scheduled for this purpose in June 2011.

A. Blower Replacement

The four existing constant-speed, multi-stage centrifugal blowers that serve the activated sludge system were installed in the late 1980s, are approaching the end of their useful lives, and represent an older, less efficient means to supply the high volumes of air needed for BOD and ammonia oxidation. Even if the two, 250-horsepower (Hp) and two, 150-Hp blowers could provide another 20 years of reliable service, at least five more of the larger 250-Hp units would be needed to augment the capacity of the existing system. This would necessitate the addition of a second blower building, of equal or greater size than the existing one. By contrast, five HST units, each 400 Hp in size, can fit within the space occupied by the four existing blowers. The newer HST technology is much more space efficient compared to multi-stage centrifugal blowers. They are also more energy efficient because

- Only one-stage of compression is needed to produce the required air discharge rate and pressure.
- The impeller shaft is support by either magnetic levitation or a cushion of air, which creates an essentially a frictionless condition compared to conventional bearings.
- Single-stage blowers have higher wire-to-air efficiencies when they operate off their design point condition, which is frequently the case (1) early in the facility planning period and (2) due to seasonal and daily variations in wastewater flows and loads.
- The VFDs and continuous on-line dissolved oxygen (DO) monitors provide for direct loop control of blower speeds, which is more efficient than throttling the inlet air to constant speed motors, which is the current mode of operation.

At design annual average flow and load conditions, expected air flow requirements at the Pueblo WRF are about 13,600 standard cubic feet per minute (scfm). Based on the performance curves for these specific HST units, 13,600 scfm can be supplied by either three blowers operating at 87 percent of capacity, or four units at 65 percent of maximum output. In contrast to constant-speed, multi-stage centrifugal units, HST blowers get progressively more efficient at greater turndown ratios. Therefore, this comparative evaluation was performed assuming four HST blowers in service at design annual average conditions. Accordingly, and as illustrated in Table 1 (at back of this memo), the average power draw savings by converting to HST blowers is projected to be 94 Hp.

Table 1 also illustrates that the capital costs to retrofit the existing blower building with five new VFD-equipped HST units is about $1,550,000. This is less expensive than adding five more of the constant speed, multi-stage centrifugal compressors and constructing a second blower building. Clearly the retrofit of the existing blower building is less expensive on its face value and it saves 614,000 kilowatt-hours per year (kWh/yr), or $43,000 per year at the current cost for utility power, which is about $0.07 per kWh including demand charges. In effect, the payback period for blower replacement is immediate.

B. Addition of First-Stage Denitrification

As noted above, the City intends to install first-stage denitrification facilities to pre-position itself for economical compliance with Colorado's proposed nutrient quality rule, which could be promulgated in June 2011. First-stage or pre-denitrification requires the addition of mixed, but not aerated anoxic basins upstream of the oxic reactors. In addition, mixed liquor (which contains the nitrate to be reduced to nitrogen gas) must be recycled from the end of the oxic reactors to the head of the anoxic tanks.

In addition to lowering TN discharges by up to 70 percent, pre-denitrification facilities provide for soluble BOD oxidation, reducing the amount of air that would otherwise have to be supplied for this purpose. First-stage denitrification will also replenish about 35 percent of the alkalinity lost during the biological oxidation of ammonia to nitrate (nitrification). The buffering that denitrification provides eliminates the need to feed supplemental alkalinity, like sodium hydroxide, to assure that effluent pH limits are continuously met.

It seems virtually certain the City will need to install at least Bio-P removal and pre-denitrification facilities in order to comply with future nutrient quality standards. Therefore, the principal concern is building these facilities in the most economical fashion possible. The City decided that it will never be more convenient or cost-effective than to "tack" these initial nutrient removal facilities onto the ammonia compliance project. Accordingly, the BCE itself will focus on energy cost savings and not the estimated $2,442,000 in capital costs to design and construct the denitrification facilities.

Using a biological process model (BioWin by Envirosim) that was specifically calibrated for the Pueblo WRF, first-stage denitrification will reduce annual average air demands during the design year by 2,700 scfm. Based on HST blower technology, about 210 Hp

would be required to supply 2,700 scfm of air at the discharge pressure required in this specific situation.

For denitrification to work, power is required for anoxic basins mixers and mixed liquor recycle (MLR) pumps. Considering the nitrate contained in the return activated sludge (RAS), it is estimated two, 9.5-mgd MLR pumps plus a RAS flow of 50 percent of influent flow (Q) will provide a total recycle to Q flow ratio of 1.75:1, which should be sufficient to reduce final effluent nitrate concentrations to 10 mg-N/L or less.

The decrease in aeration power costs, plus the increase in electricity usage due to MLR pumping and anoxic basin mixing are summarized in Table 2 (at back of this memo). No additional energy cost is ascribed to RAS pumping since it is required whether or not biological nutrient removal (BNR) is accomplished at an activated sludge facility.

As illustrated in Table 2, the reduction in aeration power costs is just enough to offset the power required to run the first-stage denitrification facilities. But if one considers that denitrification will be a permit requirement and additional mixing and MLR pumping will be needed anyway, the reduced aeration power demands are, in effect, a “bonus” for choosing this approach to reducing TN concentrations in the final effluent.

In summary, power cost savings are not sufficient to recover the capital cost of constructing denitrification facilities. However, they represent a valuable offset so the carbon footprint of the denitrification process will essentially be neutral, or a small net reduction in greenhouse gas (GHG) emissions, not including those associated with constructing the facilities.

Attachments:

Distribution:

Gene Michael, City of Pueblo
John Lindstrom, City of Pueblo
Rich Henderson, Black & Veatch
Kevin Anderson, Black & Veatch

Table 1
Green Project Reserve Funding
Business Case Evaluation
for the Pueblo WRF[1]

Case 1 - Blower Replacement

Cost Item	Cost
1. Capital Costs for High Speed Turbine Blower Replacement	
A. Five New HST Blowers and Appurtenances	$1,100,000
B. Contractor Installation, Overhead, and Profit	$200,000
C. Design Engineering (Estimate for HST Portion of Section 2/3/5)	$250,000
Subtotal 1	**$1,550,000**
2. Capital Costs to Add More Multi-Stage Centrifugal Blowers	
A. Five More Multi-Stage Blowers and Appurtenances	$450,000
B. Second Blower Building	$850,000
C. Design Engineering (Allowance)	$350,000
Subtotal 2	**$1,650,000**
3. Net Capital Cost Savings for Blower Replacement	**-$100,000**

4. Annual Energy Savings for Blower Replacement	
4	of the new 400-Hp HST blowers in service at annual average flow/load conditions
65%	of full power at annual average flow/load conditions
9%	Improvement in efficiency for HSTs at 65% of full output power
94	Horsepower reduction with the use of HST blowers
614,000	kWh per year decrease in energy usage
$43,000	Savings per year at $0.07 per kWh
$670,000	Present worth of energy savings at SRF loan rate of 2.5% over 20 years

[1]The BCE does not include costs that are common to each option. Costs are based on October 2010 prices when the 20-City Average *Engineering News Record*-Construction Cost Index (*ENR*-CCI) stood at 8920.

Table 2
Green Project Reserve Funding
Business Case Evaluation
for the Pueblo WRF[1]

Case 2 - Addition of First-Stage Denitrification[2]

	Cost Item
1. Annual Energy Savings for Reduced Aeration Demands and Blower Usage	
210	Operating Hp decrease for reduced aeration demands[3]
1,372,000	kWh per year decrease in energy usage
2. Annual Energy Cost for MLR Pumps and Anoxic Basin Mixers	
120	Hp for MLR pumps (Assume 2 on at 60 operating Hp each at design AAF)
72	Hp for anoxic basin mixers (Assume 8 on at 9 operating Hp each)
192	Total operating Hp increase for MLR pumps and anoxic basin mixing
1,255,000	kWh per year increase in energy usage
3. Net Annual Energy Cost Savings	
18	Less Hp with first-stage denitrification
118,000	kWh per year decrease in energy usage
$8,000	Savings per year at $0.07 per kWh
$125,000	Present worth of energy savings at SRF loan rate of 2.5% over 20 years

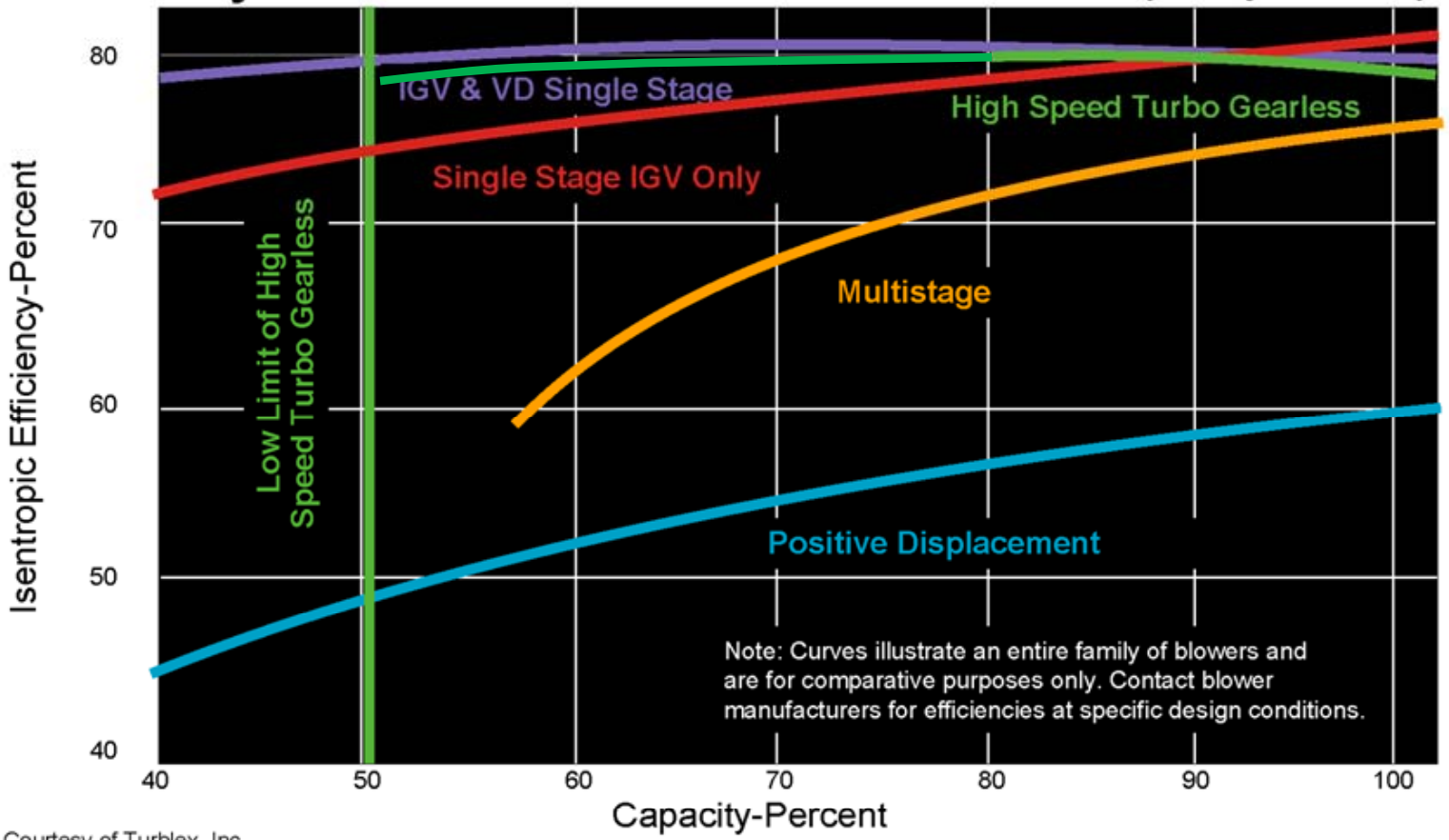
[1]The BCE does not include costs that are common to each option. Costs are based on October 2010 prices when the 20-City Average *Engineering News Record*-Construction Cost Index (*ENR*-CCI) stood at 8920.

[2]The total capital cost opinion for the anoxic basins, mixers, MLR pumps, and associated design engineering is estimated to be $2,442,000.

[3]First-stage denitrification will reduce average airflow requirements by about 2,700 scfm at the design annual average flow of 15.3 mgd. This savings equates to about 210 Hp based on the performance curves for one of the new HST blowers being installed at the Pueblo WRF.

Efficiency Comparison

Efficiency vs. Turndown of Various Blowers (Compressors)



Courtesy of Turblex, Inc.