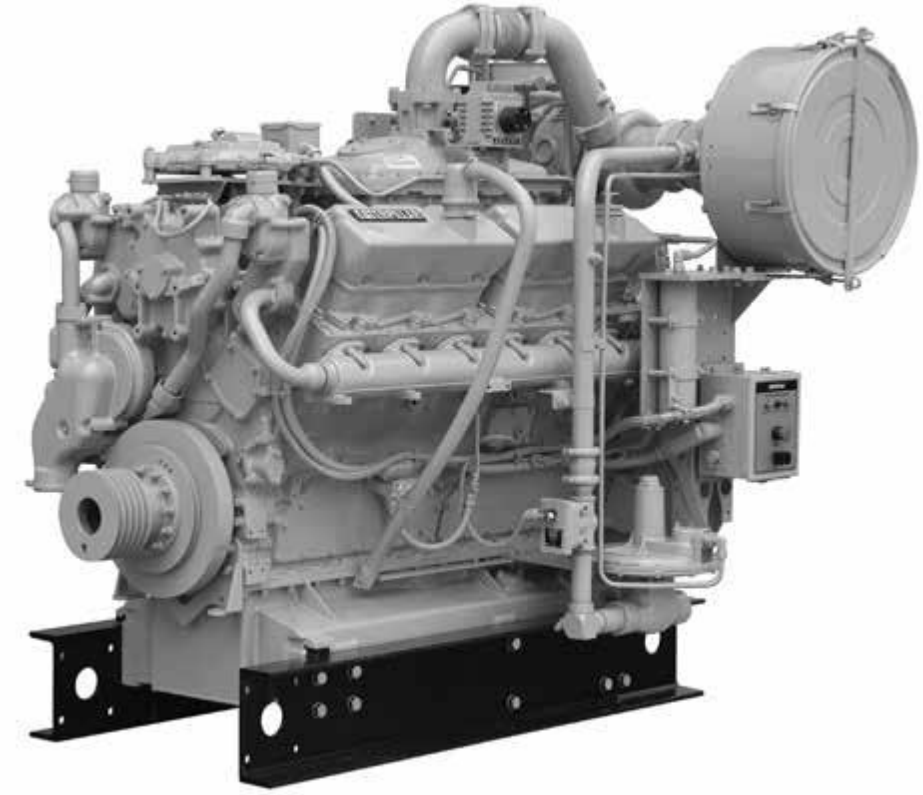
King County

BLACK RIVER NEEDS ASSESSMENT AND CAPITAL IMPROVEMENT PLANNING

KING COUNTY, WASHINGTON



TASK 5 — EVALUATE NATURAL-GAS-FIRED ENGINES TECHNICAL MEMORANDUM

FEBRUARY 2015

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FEBRUARY 2015

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TABLE OF CONTENTS

TABLES

FIGURES

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5. EVALUATE NATURAL-GAS-FIRED ENGINES

5.1. INTRODUCTION

The Black River Pump Station (BRPS) contains two 475 Hp Mitsubishi Model S6N-PT turbocharged diesel engines, which are used to power flood control pumps (P2 and P4). These pumps are critical to the wet-weather operation of the pump station, as they pump flows exceeding the 75-cfs capacity of P1, the only electric motor powered flood control pump in the BRPS. Since these engines were installed in 1985, each has operated an average of 300 hours per year. These engines are recommended for replacement with new diesel engines in the Task 2 Needs Assessment Technical Memorandum due to unavailability of some spare parts, and difficulty in obtaining other spare parts, both factors contributing to oil leakage concerns.

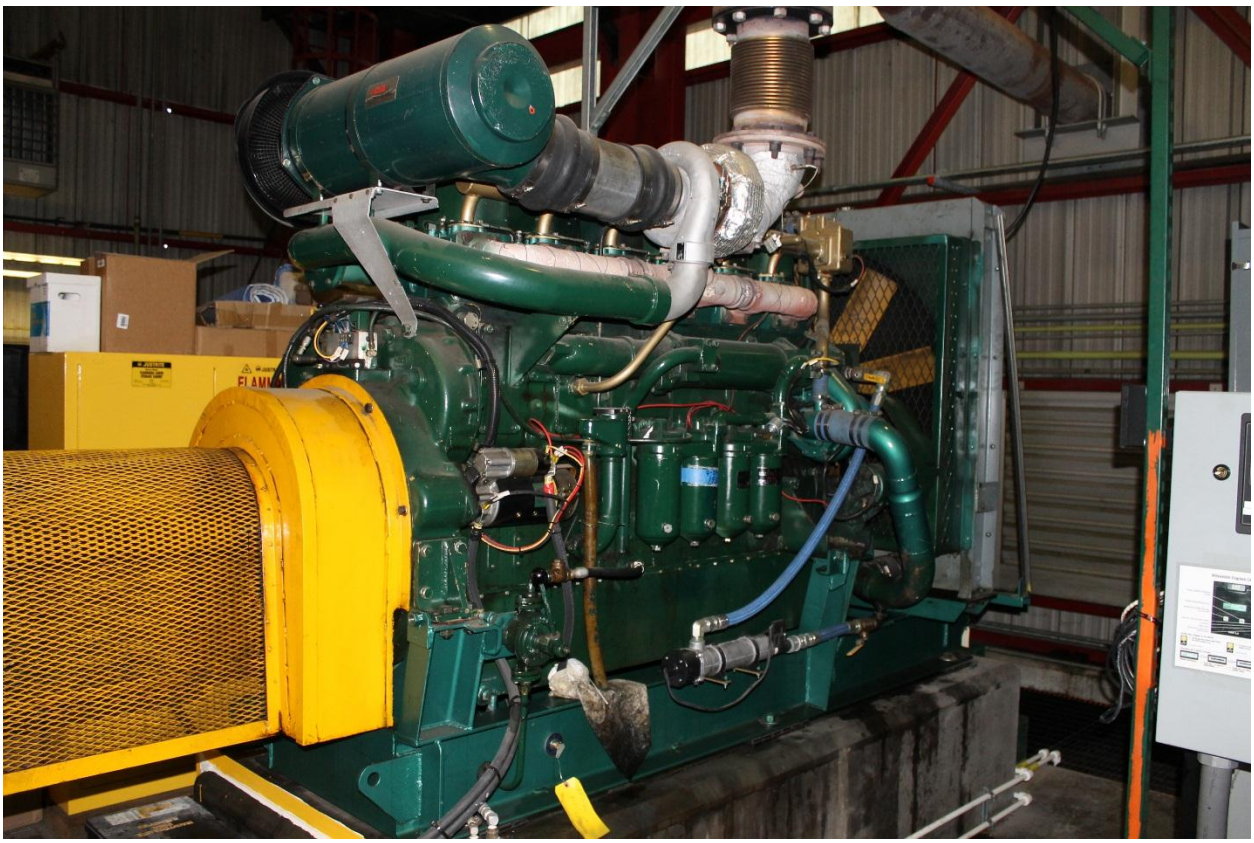

Figure 5-1 Mitsubishi Model S6N-PT Turbocharged Diesel Engine for Pump P2

This evaluation compares natural-gas-fired engines to diesel engines, to allow the County to plan the purchase of the recommended style of engine for the replacement of the Mitsubishi engines. This evaluation includes the following:

- Description and estimated cost for both styles of engines.
- Feasibility and estimated cost of increasing the capacity of the natural gas service to the BRPS to serve the natural gas engines.

- Evaluate fuel source reliability for both styles of engines
- Discuss issue of lower use rate of diesel fuel and impacts on fuel quality.
- Compare the following for both styles of engines:
    - Operation and maintenance (O&M) requirements
    - Emissions
    - Noise and safety issues

5.2. REPLACEMENT ENGINES DESCRIPTION/COST

NC Machinery (Tukwila, WA) assisted Tetra Tech in the following analysis by providing engine specifications and costs for both styles of engines. NC Machinery also provided general information on O&M issues, emissions, and other issues. The cost estimates are for the engine only (i.e., no exhaust piping or silencer costs are included).

5.2.1. REPLACEMENT DIESEL ENGINE

The existing Mitsubishi engines produce 475 bhp at 1,800 rpm and are cooled by frame-mounted radiators at the front of the engine. They use electric starters and batteries.

The Task 2 Needs Assessment Technical Memorandum includes a recommendation to replace the Mitsubishi engines with new Caterpillar C18 ACERT turbocharged diesel engines that produce 575 bhp at 1,800 rpm. These engines produce 475 bhp (the same as the existing Mitsubishi engines) at 83% load.

As discussed in the Task 2 Needs Assessment Technical Memorandum, the estimated construction cost of these engines is $120,000 - $170,000 each (for Tier 3 or Tier 4 emissions respectively). The Environmental Protection Agency (EPA) has established four tiers of emission standards for diesel engines used in a wide range of non-road applications. The Puget Sound Clean Air Agency (PSCAA) is responsible for administering air quality regulations in King County.

Tier 3 emissions standards apply to diesel engines used for emergencies, including emergency generators as well as engine-driven flood control pumps. Equipment authorized for Tier 3 emissions can be run an unlimited amount of time during emergencies and up to 100 hours per year during non-emergencies, but only for maintenance and exercising. Emergencies are easily defined as power outages for generators, therefore the County's backup generators at their pump stations would be classified as Tier 3. However, no definition for what constitutes an emergency was located for flood control pumps. It appears that this determination is left up to the agency responsible for administrating the EPA air quality regulations. Further discussions with PSCAA will be necessary to determine if a Tier 3 classification would be possible for these engines.

For the purposes of this analysis Tier 4 emissions limits are assumed to apply. The estimated cost of replacing the two Mitsubishi engines with new Tier 4 diesel engines includes engineering ($60,000) and construction costs for a total estimated cost of $400,000.

5.2.2. REPLACEMENT NATURAL GAS ENGINE

The natural gas engine selected for this evaluation is the Caterpillar G3412C (LE) gas petroleum engine. The rated capacity of these engines is 637 bhp at 1,800 rpm. These engines would produce 477 bhp (approximately the same as the existing Mitsubishi engines), at 75% load. The additional horsepower is desirable for a natural gas engine to smoothly ramp the engine up to speed while powering the flood control pump.

As will be discussed in the next section, a new service consisting of 2-inch diameter polyethylene (PE) gas line, approximately 250 feet long, will be required from the main in Monster Road to a new gas meter near the BRPS. PSE has indicated that this service would be installed at no cost.

The estimated cost for the replacement of both Mitsubishi engines with gas engines includes engineering ($110,000) and construction costs for a total estimated cost of $650,000.

5.3. GAS AVAILABILITY AND COST TO SERVE SITE

Tetra Tech submitted an application to Puget Sound Energy (PSE) to determine the feasibility and cost of providing sufficient gas service to the Black River Pump Station for operating these engines. The CAT G3412C LE engines each require 4,863,000 BTUH of natural gas at a pressure of 1.5 psi at full load. This energy requirement can be converted to a gas flow rate based on the therm factor of the PSE gas (the BTU equivalent of a volume of gas at standard temperature and pressure). 4,863,000 BTUH equates to about 48 hundred cubic feet (ccf) per hour per engine.

Dave Lesinski, a Senior PSE Engineering Specialist, evaluated the gas availability for this site to determine the feasibility and cost to provide service for these engines (9,726,000 BTUH or 96 ccf/hour total for the engines, plus serve current building heating needs). Note that the service is based on full load of the selected engine, however this engine requires only 75% of its full load to power the flood control pumps.

A summary of the PSE analysis is as follows (Lesinski, D., December 10, 2014, personal communication):

- PSE notes in its review of our request for a significantly higher capacity gas service for this station that it has performed a "Feasibility Review," not a formal load approval or approval of service.
- The existing gas service is 3/4" wrapped steel and the maximum capacity is 1,000,000 BTUH (10 ccf/hour), This service supplies the two unit heaters in the pump building, and would need to be replaced with a higher capacity service if natural gas engines were installed.
- The new service will deliver a higher pressure (2 psi) for the natural gas engines. The existing gas unit heaters are running off 6" water column (about 0.22 psi), therefore a branch line downstream of the gas meter will need to be regulated down to 6" w.c. to serve these heaters.
- Reviewing the current configuration of the intermediate pressure (IP) system, RS-1565 and existing customers being served by the IP system, PSE indicates that it will install the gas service (2" PE, approximately 250 feet long) and meter for no cost. This service would be adequate for the new load of 101 ccf/hr. This is lower than the full load requirement for the engines (96 ccf/hour) plus the unit heaters (10 ccf/hour), however the actual load requirement for the engines (75% full load) is approximately 72 ccf/hour, therefore the estimated demand is approximately 82 ccf/hr. This indicates that the new service may have a limited amount of excess capacity for potential future demands.
- PSE indicates that if any additional load is to be added, the service would have to be reviewed to determine if it is still adequate.
- Project is within emergency section 31 (This refers to a portion of the PSE gas distribution system that is considered to have adequate isolation capability in case of a break in the gas main. This indicates that no new isolation valves would be required if the higher capacity service were to be installed).

5.4. NON-MONETARY EVALUATION

5.4.1. FUEL SOURCE RELIABILITY

Natural gas reliability is good, but a pipeline can be shut off due to an earthquake, vandalism, or other reason beyond the County's control.

The reliability of the diesel fuel system at the BRPS is high due to the recent upgrade of the on-site storage tanks and distribution system. Diesel engines start more reliably and have much faster starting times, per NC Machinery.

5.4.2. MAINTAINING DIESEL FUEL QUALITY

Diesel fuel will eventually break down if left in storage for a long period of time (for the purposes of this evaluation, more than a year). If the Mitsubishi engines are replaced with natural gas engines, only the Waukesha engines, which are seldom used, will continue to use this fuel supply, so the diesel fuel in the large tanks outside the pump building will sit for years without being used up. A large-scale fuel cleaning system can be purchased to extend the fuel life for a total cost, including design and construction of about $70,000. A service could also be hired periodically to perform this work.

5.4.3. O&M COMPARISON

Maintenance costs are similar for both engine styles, but natural gas engines are larger due to the fuel's lower heat content, so parts are more expensive. Gas engines also require spark plugs, whereas diesel engines don't.

Diesel engines require oil changes every 500 hours and particulate filter service every 5,000 hours; natural gas engines require oil changes every 750 hours (gas engines don't have particulate filters).

The fuel supply for natural gas is maintenance free, whereas a diesel fuel storage and distribution system requires maintenance. Because the BRPS already has a diesel fuel storage and distribution system, this advantage would not apply to this evaluation.

5.4.4. FUEL COST

The CAT C18 diesel engine uses 28.5 gallons of fuel per hour at full load at 1,800 rpm. This engine would use approximately 23.5 gallons of fuel per hour at 83% load.

The CAT G3412C natural gas engines use 3,800,000 BTUH at 1,800 rpm and 75% load. Assuming 300 hours operation per year for each engine, and current fuel prices, the cost to operate two styles of engines is:

- Diesel Fuel: 7,050 gallons/year @ $1.86/gal = $26,226 per year
- Natural Gas: 10,945 ccf/year @ $0.96/ccf = $ 21,014 per year

This evaluation indicates that natural gas engines would provide a savings of $5,212 per year based on current fuel prices (current prices are based on quotes from Associated Petroleum Products (APP) and Puget Sound Energy (PSE) on 12/19/2014). The potential fuel savings with natural gas engines will vary over time with fluctuations in the prices of both fuels.

5.4.5. EMISSIONS

Natural gas burns cleaner than conventional gasoline or diesel fuel due to its lower carbon content. However, modern diesel engines with advanced Tier 4 emissions equipment and ultra-low sulfur diesel

(ULSD) fuel can burn cleaner than natural gas. ULSD fuel contains a maximum of 15 ppm sulfur, and new oil formulations to support the new Tier 4 engine technology. As mentioned previously, this evaluation assumes that the new diesel engines at the BRPS will meet U.S. EPA Tier 4 emissions, however, for the purposes of this evaluation, Tier 3 emissions, using standard diesel fuel, are also discussed.

A potential issue is that if Tier 4 diesel engines are installed at the BRPS, the Waukesha engines would also have to also use the ULSD fuel. Most conventional diesel engines rely on sulfur and other chemical components in the fuel to lubricate the fuel pump, injectors, etc. Some conventional diesel engines can operate adequately with ULSD fuel by using additives to provide proper lubrication. However, the service department of Continental Engines in Greenville, S.C., a major supplier of Waukesha engines, says that these engines will run fine on ULSD fuel.

The natural gas is assumed to meet U.S. EPA Spark Ignited Stationary NSPS Emissions for 2007/8.

Table 5-1 shows the emission limits for the Diesel Tier 3 and Tier 4 engines, and the estimated emissions for the natural gas engine (full load assumed). Tier 3 limits are shown for information only.

Table 5-1. Emission Limits for Tier 3 and Tier 4 engines, and Estimated Emissions for Natural Gas Engines

Emissions (g/hour)	Diesel Tier 3 Emission Limits	Diesel Tier 4 Emission Limits	Natural Gas Engine Emissions
Nitrogen Oxides (NOx)	Not Required	172	1,274
Carbon Monoxide (CO)	1,502	1,502	1,255
Carbon Dioxide (CO_2)	Unspecified	Unspecified	305,123
Volatile Organic Compounds (VOC)	N/A	N/A	204
Non-Methane Hydrocarbons (NMHC)	Not Required	82	N/A
Particulate Matter (PM)	86	9	N/A

5.4.6. NOISE

According to NC Machinery, gas engines are usually slightly quieter than diesel engines, however, manufacturer's noise level data for the two styles of engines from the manufacturer was not obtained.

5.4.7. SAFETY

According to NC Machinery, natural gas engines have a record of safety that is comparable to diesel engines.

Diesel fuel safety advantages:

- Low flammability compared to natural gas.

Natural gas safety advantages:

- No risk of fuel spill.
- Leaks can easily be detected by the human nose due to the addition of an odorant to the natural gas.
- A combustible gas detector can be used to monitor equipment areas where natural gas is used.

5.5. CONCLUSION

Table 5-2 summarizes the evaluation of natural gas engines.

Table 5-2. Summary of Natural Gas Engine Evaluation

Criteria	Diesel Tier 4 Engine	Natural Gas Engine	Comments
Estimated Cost	$400,000	650,000	Includes engineering and construction costs.
Fuel Source Reliability	Good	Fair	Gas service at risk due to earthquake and man-made damage.
Maintaining Diesel Fuel Quality	Good	Poor	Low use of diesel if natural gas engines are installed
O&M requirements	Equal	Equal	
Fuel Costs	$26,000/year	$21,000/year	
Emissions	Good	Fair	Tier 4 emissions are lower than the emissions provided by Caterpillar for the selected natural gas engine.
Noise	Fair	Good	
Safety	Fair	Good	Lower risk of fuel spill with natural gas engine

Based on the lower cost, better fuel source reliability, and the ability to maintain diesel fuel quality, it is recommended that the County select the Tier 4 diesel engine for the replacement of the Mitsubishi engines.

REFERENCES

Lesinski, Dave. December 10, 2014. Personal Communication (email notification of Job #501430924 to Neil Thibert, Tetra Tech, Inc., Seattle, WA). Puget Sound Energy. Renton, WA.