May 2010
NEWPCC Pump Tests

TECHNICAL MEMORANDUM CH2MHILL

NEWPCC Raw Sewage Pump Replacement Project – Pump Tests

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CH2M HILL PROJECT NUMBER: 390903

Purpose

The purpose of this technical memorandum is to document the approach and summarize the findings of the pumping tests performed by CH2M HILL in co-operation with the City of Winnipeg personnel and Power and Mine to evaluate the performance of NEWPCC raw sewage pumps MP-5 and MP-6.

Pumping System Description

The existing NEWPCC raw sewage pumping consists of six (6) close coupled horizontal type raw sewage pumps, numbered MP-1, MP-2, MP-3, MP-4, MP-5 and MP-6. Pumps are located in three separate 17.4 m deep dry wells: dry well 1 contains MP-5 and MP-6, dry well 2 contains MP-3 and MP-4 and dry well 3 contains MP-1 and MP-2.

The pump suction lines are connected to one of two conduits called the east and west suction headers, positioned on the east and west sides of the dry wells. Pumps MP-1, MP-5 and MP-6 are connected to the east suction header and pumps MP-2, MP-3 and MP-4 are connected to the west suction header. The suction pipe for MP-1 is 750 mm diameter and the rest are all 900 mm. There are isolating actuated gate valves on all suction pipes.

The suction headers are connected to a wet well (formerly called a surge well) which receives inflow from the main sewage interceptor.

Pumps MP-2 and MP-4 are equipped with liquid slip variable speed drives from the 1960s, while pumps MP-1, MP-3 and MP-6 have constant speed drives and pump MP-5 has a two speed motor.

Pumps discharge to a discharge well via individual pipes equipped with magnetic flow meters. The discharge well is an open head tank with a fluctuating level, connected to the plant head works. The discharge pipes each have vacuum breaker valves installed at the highest point preventing back flow (siphoning) from the discharge chamber to the pumps.

Pump Test Objectives

It was recommended in the NEWPCC Raw Sewage Pump Replacement Project Conceptual Design Report (July 2010) that a field test be undertaken of dry well No. 1 The report noted that configuration of the existing dry wells does not conform to the Hydraulic Design Institute recommended design standards, which may result in pump performance issues. The testing was recommended to investigate actual pumping performance to determine if any detrimental effects could be observed and confirmed (recommendation number 5).

The potential issues that may result from an installation not meeting industry accepted standards and those of the Hydraulic Institute Standards were identified as follows:

- Velocities – Suction pipe velocities are recommended to be less than 2.4 m/s although higher velocities are acceptable provided piping design delivers a smooth inlet flow to the pump suction. In fact, the pump inlet nozzle itself may be sized such that the inlet velocity exceeds 2.4 m/s, which is not a design parameter and should not affect the performance of the pump.

- Suction Pipe - The Hydraulic Institute recommends that there be a straight section of suction pipe immediately upstream of the pump. There are to be no flow disturbing fittings closer than 5 pipe diameters from the pump. For severe pipe bends, the recommended upstream distance is 8 pipe diameters.

- Inlet Configuration – Inlet flows that pass through two planes may cause more disturbance than those through only one plane. For the case of dry well No. 1, the configuration causes a two-plane flow. The configuration causes swirl in the inlet piping that may impact the pump performance. The swirl effect is different depending on the swirl direction. Pre-rotation will increase the performance of the pump, while an anti-pre-rotation will work against the pump and reduce its performance. Pumps MP-5 and MP-6 in dry well No. 1 rotate in opposite directions, so it is expected that the opposite effect would occur on each.

- Net Positive Suction Head –NPSHR is a characteristic specific to each pump and must be lower than the NPSHA, which is a characteristic of the system. One of the objectives of the test was to collect data to confirm the NPSHA. The suction header is a complex shape with varied size and the interior condition and resulting head losses are not known which impact the degree of precisions in calculating the head losses.

The testing was planned to evaluate the pump performance at different levels of water in the wet well and thus at different suction pressure and conditions (velocity) by measuring flow rate using existing magnetic flow meters installed on the individual discharge pipes of each pump and measuring differential pressures developed by the pump using pressure gauges installed on the suction and discharge pipes of each pump and compare those results to the original pump curves.

In addition to measurement of the hydraulic parameters, pump vibration was measured in several points on the pump. Pump vibration can be used to identify pump installation and operational issues by noting and analyzing the velocity and amplitude of the vibration at various locations under different operational conditions.

Test Setup

The objective was to test the pumps in dry well No. 1, which involved testing pumps MP-5 and MP-6 individually and running in combination. A further test was performed on pump MP-3 as a base case test, as it is an identical pump to MP-6, and is also constant speed. The resulting tests were:

1. MP-5 Low Speed
2. MP-5 High Speed
3. MP-6
4. MP-6 and MP-5 High Speed
5. MP-3 (comparison to MP-6)

Pressure Gauges

Prior to the test pressure gauges were installed on the suction and discharge piping of pumps to be tested. Locations of pressure gauges and elevations relative to the center line of the pump are shown in the Exhibit 1.

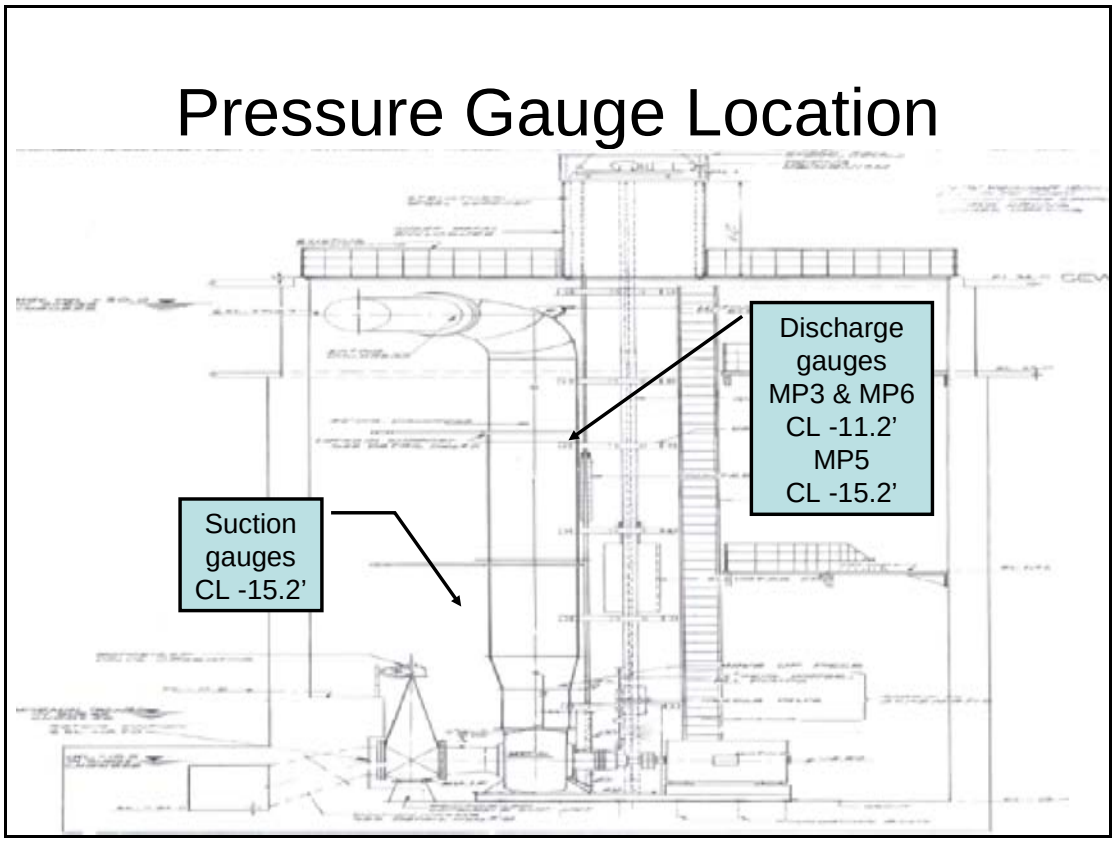

Exhibit: 1 Locations and relative elevation of pressure gauges

During the test a high fluctuation was noted in the pressure readings, and while they are considered to provide a reasonable indication for estimation of pump performance, higher quality equipment would have been useful for more accurate hydraulic observations.

Vibration Measurement Locations

Vibration testing was performed by Power & Mine. A technician set up the equipment for each pump prior to the tests and then relocated the equipment for the subsequent pump tests. Vibration was measured at the following locations:

- Coupling End: Vertical and Horizontal
- Impellor End: Vertical, Horizontal and Axial
- Casing: Radial

Test Protocol

The pumps being tested were all constant speed, with MP-5 having a low and high speed setting; neither of the variable speed pumps were tested. The test procedure involved testing of each pump (or combination) at five different wet well levels in order to obtain data points at as broad of range as possible on the pump curve.

The target wet well levels were (in feet City datum):

- -6 feet
- -10 feet
- -13 feet
- -16 feet
- -17 feet

The pump test elevations relative to the wet well are shown in Exhibit 2.

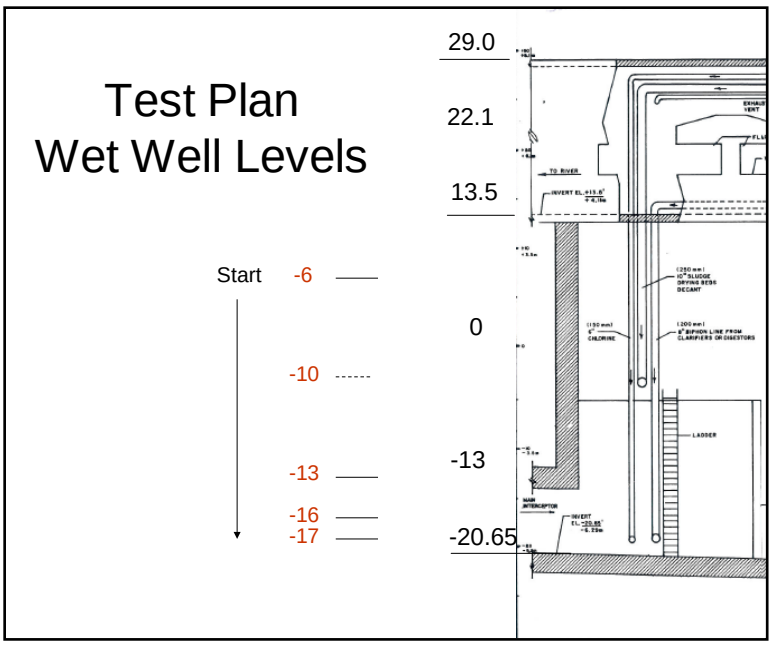

Exhibit: 2 Wet Well Test Levels

The testing was planned to take place over dry weather conditions such that the inflow rate would be consistent with known values and could be reasonably anticipated. Because of the diurnal fluctuations, real time control of the assisting pumps was required to maintain the wet well level with the test pumps running. Only pumps from the opposite suction header were permitted as assisting pumps, to avoid interference with the suction header hydraulic observations.

The pumps discharge independently into a discharge well, with the pipes looping above the surface of the discharge well and discharging vertically downward, as shown in Exhibit 3. The vertical loop causes a siphon effect when the pumps are running, with the water level in the discharge well being the discharge control point. A siphon breaker on the loop opens when the pump stops and the water in the loop is allowed to backflow through the pump into the suction header. The siphon breaker was confirmed to be closed for the pump testing.

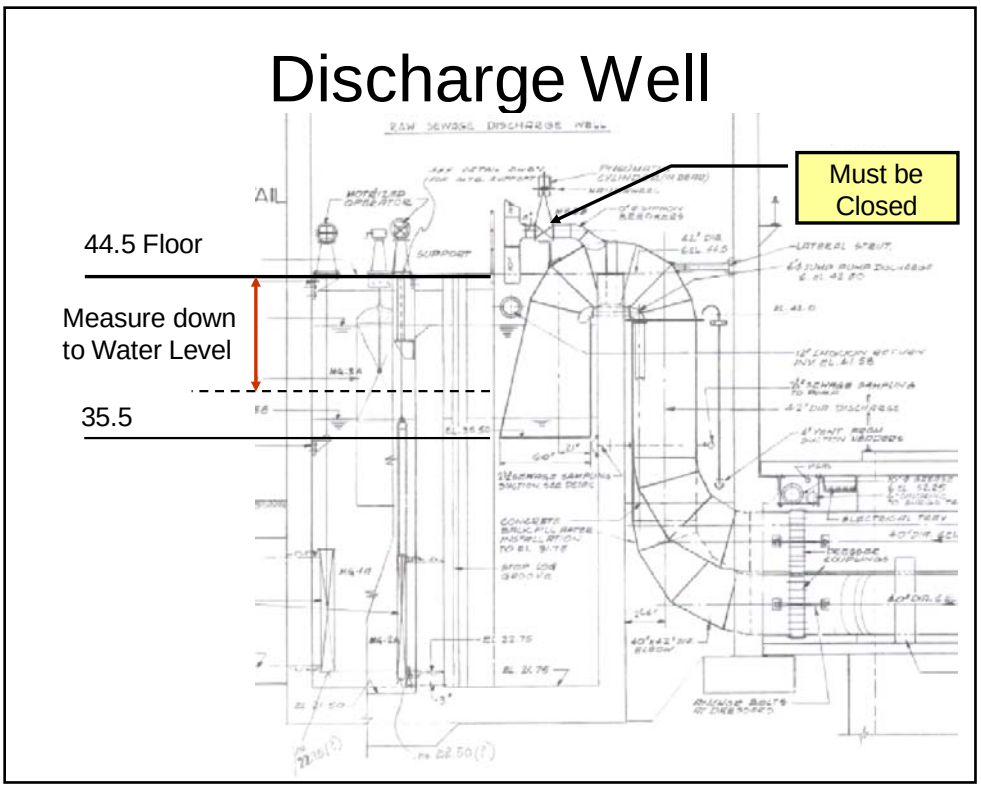

Exhibit: 3 Discharge Well Configuration

Testing Team

The testing team consisted of three groups of people:

1. A plant operator located in the control room with responsibility to remotely operate the pumps to maintain the wet well level as close as possible to the target level. Level control was made by selecting pumps, and starting, stopping and controlling their speed as needed. The operator transmitted information by radio to the rest of the test team. Flows for each pump, total flow, and water levels in the wet well were recorded by the plant control system, and this data was later used for the evaluation of test results.

2. One City staff in the discharge well to manually measure and record a distance from the water level in the discharge well to the walkway in the area at the precise time when requested by the test coordinator.

3. Three people were located in the dry wells (CH2M HILL and Power and Mine) at the test pump location. One person was responsible for coordinating the test, one for reading and recording pressure gauges and the third for reading vibration instruments.

Pump Test Results

The onsite pump testing took place on April 8 between 0938 and 1500 hours and on April 9 between 0919 and 1035 hours.

The pumping rate was kept below normal in the early morning hours, allowing the level in the wet well to build up for the testing. As illustrated in Exhibit 4 the testing started at minute 578 (0938 hours), with the pumping rate increased to attain a surge well level of -6.0 feet. The testing continued through the day by running pumps to lower and then maintain the desired wet well level, while recording the test information.

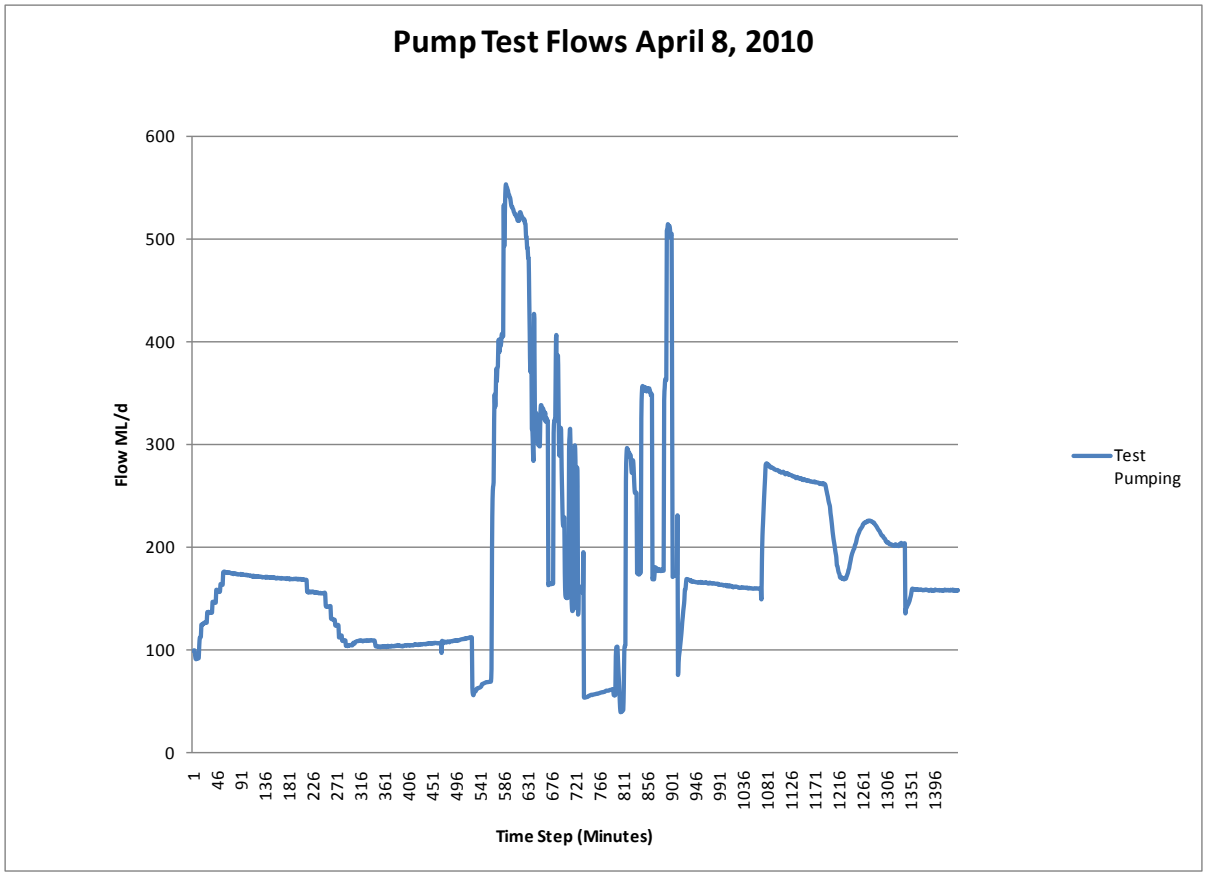

Exhibit 4: Pumping Rates during April 8, 2010 Pump Tests

Test results are presented in tables: MP-5 Low Speed (LS) results - Table 1, MP-5 High Speed (HS) results - Table 2, MP-6 results - Table 3, MP-6 and MP-5 HS results - Table 4 and MP-3 results - Table 5.

MP5 Low Speed Test Results

Tested pump number	Date and Time	Target wet well level	Actual wet well level	Discharge well measurement	Discharge well level	Water level difference	Suction pressure reading	Corrected discharge pressure	Pressure differential	Tested pump flow	Assisting pump flow	Assisting pump rpm	Assisting pump flow	Assisting pump flow	Assisting pump rpm	Total flow	Vibration	Amplitude			
							MP5	MP5	MP5	MP5 LS	MP4	MP4	MP3	MP2	MP2		Position	Horizontal	Vertical	Axial	C
MP5 LS	4/8/2010 9:38	-6	-6.06	6	38.5	44.56				104	127.4	459.21	0	164	442.38	395.2	A	0.075	0.078	0.113	0.054
	4/8/2010 9:39		-6.12							106.55	127.15	458.96	0	165.4	443.48	397.8	B	0.095	0.114		
	4/8/2010 9:40		-6.28				9.92	58.66	48.74	102.35	126.45	459.09	0	174.55	457.23	405.65					
	4/8/2010 9:41		-6.34							102.2	126.45	458.71	0	174	457.36	407.45					
	4/8/2010 9:42		-6.36							104.2	126.15	458.58	0	173.75	457.11	404.55					
	4/8/2010 9:43		-6.48							103.15	125.7	458.58	0	173.65	450.23	404.9					
	4/8/2010 9:44		-8.01							92.65	122.05	458.34	174.65	147.6	425.85	529.59					
	4/8/2010 9:45		-8.61							94.85	119.95	458.96	179.05	89.8	363	492.24					
MP5LS	4/8/2010 9:59	-10	-10.03	4.8	39.7	49.73				86.8	108.5	458.2	170.95	165.5	455.23	530.69	A	0.081	0.086	0.139	0.06
	4/8/2010 10:00		-10.17				8.77	59.12	50.35	86.65	108	458.08	168.9	165.9	454.62	530.59	B	0.101	0.118		
	4/8/2010 10:01		-10.2							85.6	107.2	458.09	169.9	165.75	454.61	528.75					
	4/8/2010 10:02		-10.33							84.65	107.5	458.09	169.7	165.45	454.98	527.98					
	4/8/2010 10:03		-10.45							84.75	106.95	457.97	169.2	164.5	454.11	525.69					
	4/8/2010 10:04		-10.49							85.7	106.5	457.82	169.3	164.8	454.11	524.8					
	4/8/2010 10:05		-10.62							84.25	105.95	457.97	168.35	164.45	454.11	523.09					
	4/8/2010 10:06		-10.71							84	106.5	457.7	167.4	164.35	454.48	523.23					
MP5LS	4/8/2010 10:29	-13	-12.99	5.2	39.3	52.29				89.55	100.25	457.7	163.25	137	423.85	490.99	A	0.087	0.086	0.161	0.062
	4/8/2010 10:30		-13.14				6.46	59.12	52.66	90.2	99.75	458.09	162.85	128.7	415	480.8	B	0.102	0.123		
	4/8/2010 10:31		-13.17							89.3	99.9	457.7	160.85	127.9	415.6	480.8					
	4/8/2010 10:32		-13.32							90.15	100.55	457.95	162.95	81.05	362.71	442.95					
	4/8/2010 10:33		-13.03							92.2	66.9	403.09	164.15	74.5	361.88	406.7					
	4/8/2010 10:34		-12.83							96.3	33.6	390.74	164.4	76.5	361.78	370.59					
	4/8/2010 10:35		-12.99							92	63.85	406.95	164.4	77.4	363	394.99					
	4/8/2010 10:36		-13.07							92	62.3	407.58	162.4	77.15	363.38	395.3					

Note: Flows in ML/d, elevations in feet, pressure in feet of water, amplitude in inches/s

Table 1. MP-5 Low Speed Test Results

MP5 High Speed Test Results

Tested pump number	Date and Time	Target wet well level	Actual wet well level	Discharge well measurement	Discharge well level	Water level difference	Suction pressure reading	Corrected discharge pressure	Pressure differential	Tested pump flow	Assisting pump flow	Assisting pump rpm	Assisting pump flow	Assisting pump flow	Assisting pump rpm	Total flow	Vibration	Amplitude			
							MP5	MP5	MP5	MP5 HS	MP4	MP4	MP3	MP2	MP2		Position	Horizontal	Vertical	Axial	C
MP5 HS	4/9/2010 9:52	-6	-7.71	7.45	37.05	44.76				200.6	0	0	0	0	0	200.95	A	0.097	0.097	0.127	0.064
	4/9/2010 9:53		-7.44				7.61	55.43	47.82	202.35	0	0	0	0	0	200.15	B	0.093	0.116		
	4/9/2010 9:54		-7.14							202.35	0	0	0	0	0	202					
	4/9/2010 9:55		-7.35							200.25	0	0	0	0	0	201.6					
	4/9/2010 9:56		-7.49							200.25	0	0	0	0	0	199.15					
	4/9/2010 9:57		-7.48							201.5	0	0	0	0	0	200.85					
	4/9/2010 9:58		-7.47							201.55	0	0	0	0	0	199.8					
	4/9/2010 9:59		-7.38							201.5	0	0	0	0	0	200					
MP5HS	4/8/2010 13:35	-10	-9.72	6.75	37.75	47.47				187.3	106.6	459.46	0	0	0	288.9	A	0.09	0.092	0.142	0.064
	4/8/2010 13:36		-10.02				5.78	56.35	50.57	187.15	108.65	460.08	0	0	0	296.4	B	0.098	0.125		
	4/8/2010 13:37		-10.15							185.35	108.1	459.95	0	0	0	294.8					
	4/8/2010 13:38		-9.86							187.2	108.35	454.23	0	0	0	294.45					
	4/8/2010 13:39		-9.72							187.1	100.15	446.37	0	0	0	288.15					
	4/8/2010 13:40		-9.87							183.55	106.35	459.96	0	0	0	291.95					
	4/8/2010 13:41		-9.95							181.75	107.65	459.84	0	0	0	289.7					
	4/8/2010 13:42		-9.93							181.85	107.3	459.94	0	0	0	289.9					
MP5 HS	4/8/2010 10:41	-13	-13.25							159.7	20.45	377.4	161.95	76.35	367.12	426.64	A	0.09	0.102	0.152	0.067
	4/8/2010 10:42		-13.56							179.7	20.1	378.15	164.05	78.4	367.62	382.45	B	0.098	0.117		
	4/8/2010 10:43		-12.89							186.7	38.5	392.73	0	88.75	372.62	313.4					
	4/8/2010 10:44		-13.02				3.46	57.05	53.59	184.55	54.95	401.47	0	89.25	372.78	325.45					
	4/8/2010 10:45		-13.12	6.6	37.9	51.02				184.05	56.95	401.22	0	88.9	372.62	330.49					
	4/8/2010 10:46		-13.09							183.85	41.9	382.63	0	84.9	367.88	318.24					
	4/8/2010 10:47		-13.03							183.85	33.7	381.77	0	84.75	367.75	305.95					
	4/8/2010 10:48		-13.07							181.7	33.4	382.48	0	85.1	367.66	301.99					
MP5HS	4/8/2010 12:06	-16	-15.64							160.1	0	0	0	0	0	159.4	A	0.092	0.105	0.131	0.064
	4/8/2010 12:07		-15.54	7.65	36.85	52.39				160.2	0	0	0	0	0	159.1	B	0.109	0.128		
	4/8/2010 12:08		-15.45				1.15	56.35	55.2	158.15	0	0	0	0	0	158.15					
	4/8/2010 12:09		-15.36							160.35	0	0	0	0	0	161.7					
	4/8/2010 12:10		-15.24							158.05	0	0	0	0	0	157.55					
	4/8/2010 12:11		-15.17							156	0	0	0	0	0	156.4					
	4/8/2010 12:12		-15.07							154.85	0	0	0	0	0	156.65					
	4/8/2010 12:13		-15.01							155.45	0	0	0	0	0	155.75					

Note: Flows in ML/d, elevations in feet, pressure in feet of water, amplitude in inches/s

Table 2. MP-5 High Speed Test Results

MP6 Test Results

Tested pump number	Date and Time	Target wet well level	Actual wet well level	Discharge well measurement	Discharge well level	Water level difference	Suction pressure reading	Discharge pressure reading	Corrected discharge pressure	Pressure differential	Tested pump flow	Assisting pump flow	Assisting pump rpm	Assisting pump flow	Assisting pump flow	Assisting pump rpm	Total flow	Vibration	Amplitude			
							MP6	MP6	MP6		MP 6	MP4	MP4	MP3	MP2	MP2		Position	Horizontal	Vertical	Axial	C
MP6	4/9/2010 9:19	-6	-4.98				9.23	54.21	61.51	52.28	200	76.75	396.85	0	0	0	276.24	A	0.082	0.075	0.059	0.043
	4/9/2010 9:20		-7.15								171.95	64.65	375.4	0	0	0	238.95	B	0.046	0.046		
	4/9/2010 9:21		-5.28								184.7	0	0	0	0	0	180.95					
	4/9/2010 9:22		-4.69	7.55	36.95	41.64					186.65	0	0	0	0	0	184.85					
	4/9/2010 9:23		-4.9								184.55	0	0	0	0	0	185.5					
	4/9/2010 9:24		-5.19								184.55	0	0	0	0	0	184.5					
	4/9/2010 9:25		-5.3								184.3	0	0	0	0	0	186					
	4/9/2010 9:26		-5.44								183	0	0	0	0	0	184					
MP6	4/8/2010 13:47	-10	-10.2	6.9	37.6	47.8					174.55	106.75	459.21	0	0	0	284.55					
	4/8/2010 13:48		-10.25				5.77	47.52	54.82	49.03	175.5	107.1	459.09	0	0	0	281.7					
	4/8/2010 13:49		-10.02								174.85	88.15	422.92	0	0	0	270.75					
	4/8/2010 13:50		-9.88								175.1	77.85	413.07	0	0	0	258.49	A				
	4/8/2010 13:51		-9.98								175.3	77.4	413.56	0	0	0	252.7	B				
	4/8/2010 13:52		-9.93								175.25	77.65	413.69	0	0	0	253.05					
	4/8/2010 13:53		-9.99								174.55	77.7	413.94	0	0	0	253.3					
	4/8/2010 13:54		-10								174.85	78	408.95	0	0	0	252.5					
MP6	4/8/2010 11:10	-13	-13.89	7.6	36.9	50.79					164.65	0	0	0	0	0	164.95	A	0.109	0.112	0.091	0.075
	4/8/2010 11:11		-13.8								164.7	0	0	0	0	0	165.15	B	0.074	0.074		
	4/8/2010 11:12		-13.81								165.3	0	0	0	0	0	164.05					
	4/8/2010 11:13		-13.8								163.1	0	0	0	0	0	164.4					
	4/8/2010 11:14		-13.77								165.2	0	0	0	0	0	164.35					
	4/8/2010 11:15		-13.75								164.9	0	0	0	0	0	164.5					
	4/8/2010 11:16		-13.74								165.3	0	0	0	0	0	164.45					
	4/8/2010 11:17		-13.7								164.95	0	0	0	0	357.91	164.75					
MP6	4/8/2010 11:24	-16	-15.71	6.6	37.9	53.61					156	46.1	388	0	122.3	409.35	332	A	0.113	0.11	0.084	0.058
	4/8/2010 11:25		-15.4				0	49.82	57.12	57.12	156	40	394.48	0	138.35	425.23	325.09	B	0.058	0.054		
	4/8/2010 11:26		-15.99								151.7	95.8	460.44	0	126	410.62	386.25					
	4/8/2010 11:27		-16.62								150.65	70.6	418.43	0	119.4	408.5	349.5					
	4/8/2010 11:28		-16.32								150.9	33.05	380.52	0	108.9	401.09	301.15					
	4/8/2010 11:29		-16.02								150.1	22.85	376.52	0	120.05	408.23	288.9					
	4/8/2010 11:30		-16.05								147.95	27	384.13	0	126.55	416.48	303.9					
	4/8/2010 11:31		-16.35								145.95	41.9	396.1	0	127.2	416.98	316.09					
MP6	4/8/2010 11:32	-17	-17.26	6.8	37.7	54.96					143.9	53.1	404.21	0	120.75	412.6	314.2	A	0.114	0.1	0.075	0.061
	4/8/2010 11:33		-17.31				-2.31	50.05	57.35	59.66	144.9	26.15	379.77	0	103.05	398.72	277.65	B	0.06	0.056		
	4/8/2010 11:34		-17.01								148.55	22.1	377.52	0	71.5	361.88	251.55					
	4/8/2010 11:35		-16.4								152.9	16.1	374.78	0	51.9	354.38	227.39					
	4/8/2010 11:36		-16.1								153	20.1	375.9	0	52.6	354.75	220.55					
	4/8/2010 11:37		-15.99								152.6	22.1	376.9	0	53.75	355	227.05					
	4/8/2010 11:38		-16								150.8	23.4	377.27	0	55	355.88	229.15					
	4/8/2010 11:39		-15.4								152.15	24.6	377.15	0	0	0	175.15					

Note: Flows in ML/d, elevations in feet, pressure in feet of water, amplitude in inches/s

Table 3. MP-6 Tests Results

MP5 High Speed and MP6 Test Results

Tested pump number	Day and Time	Target wet well level	Actual wet well level	Discharge well measurement	Discharge well level	Water level difference	Suction pressure reading	Corrected discharge pressure	Pressure differential	Suction pressure reading	Corrected discharge pressure	Pressure differential	Tested pump flow	Tested pump flow	Total flow	MP5 Vibration	MP5 Amplitude	MP5	MP5	MP5	MP6 Vibration	MP6 Amplitude	MP6	MP6	MP6
							MP5	MP5	MP5	MP6	MP6	MP6	MP5	MP6		Position	Horizontal	Vertical	Axial	C	Position	Horizontal	Vertical	Axial	C
MP5HS+MP6	4/9/2010 9:32	-6	-7.29	6.1	38.4	45.69							200.15	178.15	380.3	A	0.095	0.072	0.123	0.062	A	0.092	0.077	0.063	0.053
	4/9/2010 9:33		-6.99										197.85	178.15	379.24	B	0.092	0.116			B	0.051	0.049		
	4/9/2010 9:34		-7										197.9	178.2	377.45										
	4/9/2010 9:35		-7.07										196	176.95	374.45										
	4/9/2010 9:36		-7.22				6.92	57.51	50.59	6.23	55.74	49.51	196.25	175.65	372.34										
	4/9/2010 9:37		-7.33										197.85	175.9	373.89										
	4/9/2010 9:38		-7.38										197.85	175.85	372.24										
	4/9/2010 9:39		-7.45										198.05	175.8	371.95										
MP5HS+MP6	4/8/2010 14:03	-10	-11.56										162.15	167.95	325.15	A	0.093	0.103	0.146	0.065	A	0.101	0.095	0.077	0.057
	4/8/2010 14:04		-10.65				4.61	57.51	52.9	3.46	52.89	49.43	187.95	170.15	349.59	B	0.104	0.125			B	0.060	0.059		
	4/8/2010 14:05		-10.68	6.3	38.2	48.88							188.6	170.05	356.4										
	4/8/2010 14:06		-10.81										184.5	168	356.4										
	4/8/2010 14:07		-10.85										184.45	170	351.6										
	4/8/2010 14:08		-10.86										186.85	168.05	354.74										
	4/8/2010 14:09		-10.92										184.55	168.2	354.64										
	4/8/2010 14:10		-10.92										186.35	168.25	355.59										
MP5HS+MP6	4/8/2010 10:55	-13	-13.62										168.2	169.75	337.75	A	0.093	0.103	0.131	0.067	A	0.116	0.12	0.107	0.045
	4/8/2010 10:56		-13.7	6.45	38.05	51.67							166.65	167.5	334.4	B	0.109	0.125			B	0.075	0.092		
	4/8/2010 10:57		-13.77				2.31	57.51	55.2	2.31	55.05	52.74	166.95	166.9	332.65										
	4/8/2010 10:58		-13.84										167.7	169	334.9										
	4/8/2010 10:59		-13.92										162.95	166.8	332.25										
	4/8/2010 11:00		-14.03										167.3	166.95	331.59										
	4/8/2010 11:01		-14.07										164.15	165.9	323.85										
	4/8/2010 11:02		-14.14										160.3	164.55	330.7										
MP5HS+MP6	4/8/2010 11:56	-16	-14.92				1.15	63.27	62.12	-2.31	58.03	60.34	0	139.8	140.3	A	0.085	0.1	0.131	0.091	A	0.113	0.11	0.084	0.058
	4/8/2010 11:57		-15.9										146.4	133.65	274.3	B	0.146	0.158			B	0.058	0.054		
	4/8/2010 11:58		-16.5										172.25	128.8	299										
	4/8/2010 11:59		-16.8				1.15	57.51	56.36				165.55	128.95	284.59										
	4/8/2010 12:00		-17.13	6.75	37.75	55.05							88.6	127.9	239.25										
	4/8/2010 12:01		-17.2										85.6	130	214.4										
	4/8/2010 12:02		-17.47					49.43-	50.58-				92.35	127.35	277.59										
	4/8/2010 12:03		-17.1				-1.15						133.85	129.85	258.99										

Note: Flows in ML/d, elevations in feet, pressure in feet of water, amplitude in inches/s

Table 4. MP-5 HS and MP-6 Tests Results

MP3 Test Results

Tested pump number	Date and Time	Target wet well level	Actual wet well level	Discharge well measurement	Discharge well level	Water level difference	Suction pressure reading	Discharge pressure reading	Corrected discharge pressure	Pressure differential	Tested pump flow	Assisting pump flow	Assisting pump rpm	Assisting pump flow	Assisting pump rpm	Assisting pump flow	Assisting pump flow	Total flow	Vibration	Amplitude			
							MP3	MP3	MP3	MP3	MP 3	MP4	MP4	MP2	MP2	MP5	MP6		Position	Horizontal	Vertical	Axial	C
	4/9/2010 10:18		-7.19	7.45	37.05	44.24					183.8	0	0	0	0	0	0	184.4					
MP3	4/9/2010 10:19	-6	-7.18								184.1	0	0	0	0	0	0	184.05	A	0.081	0.079	0.059	0.041
	4/9/2010 10:20		-7.17								183.15	0	0	0	0	0	0	182.65	B	0.036	0.041		
	4/9/2010 10:21		-7.13								184.3	0	0	0	0	0	0	183.35					
	4/9/2010 10:22		-7.15								184.25	0	0	0	0	0	0	184.1					
	4/9/2010 10:23		-7.19								183.35	0	0	0	0	0	0	184.05					
	4/9/2010 10:24		-7.18								183.65	0	0	0	0	0	0	183.45					
	4/9/2010 10:25		-7.16								184.05	0	0	0	0	0	0	183.55					
	4/9/2010 10:26		-7.15								183.85	0	0	0	0	0	0	184.2					
	4/9/2010 10:27		-7.14								183.7	0	0	0	0	0	0	183.75					
	4/9/2010 10:28		-8.04								181.75	0	0	78.7	360.75	0	0	254.2					
	4/9/2010 10:29		-8.34								181.75	0	0	110.45	384.22	0	0	278.3					
	4/9/2010 10:30		-8.39								179.75	0	0	137.25	404.84	0	0	314.8					
	4/9/2010 10:31		-8.44								178.7	0	0	153.75	430.85	0	0	326.84					
	4/9/2010 10:32		-8.44								178.9	0	0	170.35	458	0	0	351.05					
	4/9/2010 10:33		-8.64								178.9	0	0	171.95	457.88	0	0	350.45					
	4/9/2010 10:34		-8.69								177.7	0	0	172.1	457.75	0	0	349.24					
	4/9/2010 10:35		-8.61				6.92	49.59	56.89	49.97	177.85	0	0	171.5	457.61	0	0	349.15					
MP3	4/8/2010 14:33	-10	-11.01	7.5	37	48.01					179.3	0	0	0	0	0	0	179.25					
	4/8/2010 14:34		-11.02								177.2	0	0	0	0	0	0	176.95					
	4/8/2010 14:35		-11.01				4.61	50.75	58.05	53.44	177	0	0	0	0	0	0	178					
	4/8/2010 14:36		-11								177.8	0	0	0	0	0	0	178.85					
	4/8/2010 14:37		-11								177.6	0	0	0	0	0	0	177.15					
	4/8/2010 14:38		-10.97								178.05	0	0	0	0	0	0	177.3					
	4/8/2010 14:39		-10.95								178.05	0	0	0	0	0	0	177.95	A	0.089	0.102	0.071	0.053
	4/8/2010 14:40		-10.96								177.65	0	0	0	0	0	0	176.85	B	0.047	0.048		
	4/8/2010 14:41		-10.95								178.15	0	0	0	0	0	0	178.4					
	4/8/2010 14:42		-10.95								177.65	0	0	0	0	0	0	177.4					
	4/8/2010 14:43		-10.95								177.45	0	0	0	0	0	0	178.3					
	4/8/2010 14:44		-10.93								177.95	0	0	0	0	0	0	177.8					
	4/8/2010 14:45		-10.93								176.6	0	0	0	0	0	0	177.25					
	4/8/2010 14:46		-11.91								174.7	0	0	0	0	167.2	0	342.74					
	4/8/2010 14:47		-11.61								174.45	0	0	0	0	187.75	0	354.85					
	4/8/2010 14:48		-11.87								174	0	0	0	0	187.95	0	363.2					
	4/8/2010 14:49		-11.84								174.3	0	0	0	0	187.95	0	361.9					
	4/8/2010 14:50		-								173.25	0	0	0	0	184.95	0	362.84					

			11.85																					
	4/8/2010 14:51		-12.89								168.9	0	0	0	0	174.2	159.75	507.45						
	4/8/2010 14:52		-13.03	5.1	39.4	52.43					171.05	0	0	0	0	176.95	168.55	508.55						
MP3	4/8/2010 14:53	-13	-13.12				3.46	51.9	59.2	55.74	169.95	0	0	0	0	171.9	168.25	513.75	A	0.098	0.112	0.085	0.073	
	4/8/2010 14:54		-13.23								170.35	0	0	0	0	174.15	168.4	511.65	B	0.057	0.055			
	4/8/2010 14:55		-13.38								169.8	0	0	0	0	176.25	168.45	512.19						
	4/8/2010 14:56		-13.55								168.5	0	0	0	0	173.9	166.3	511.9						
	4/8/2010 14:57		-13.66								168.5	0	0	0	0	172.2	167.25	508.59						
	4/8/2010 14:58		-13.9								168.65	0	0	0	0	172.25	164.95	501.45						
	4/8/2010 14:59		-14.05								167.9	0	0	0	0	172.4	167.1	503.55						
	4/8/2010 15:00		-14.22				2.31	50.75	58.05	55.74	166.7	0	0	0	0	170.3	165	504.45						

Note: Flows in ML/d, elevations in feet, pressure in feet of water, amplitude in inches/s

Table 5. MP-3 Test Results

Due to variable influent rate and limited pumping rate flexibility target wet well depths were not always possible to maintain - actual wet well depths are indicated on the tables.

The pump operating points recorded during the test and presented in the above tables were plotted on the original pump curves. The pump performance for MP-6 is plotted in Exhibit 5, with flow units presented in the original units of Imperial Gallons Per Minute (Igpm).

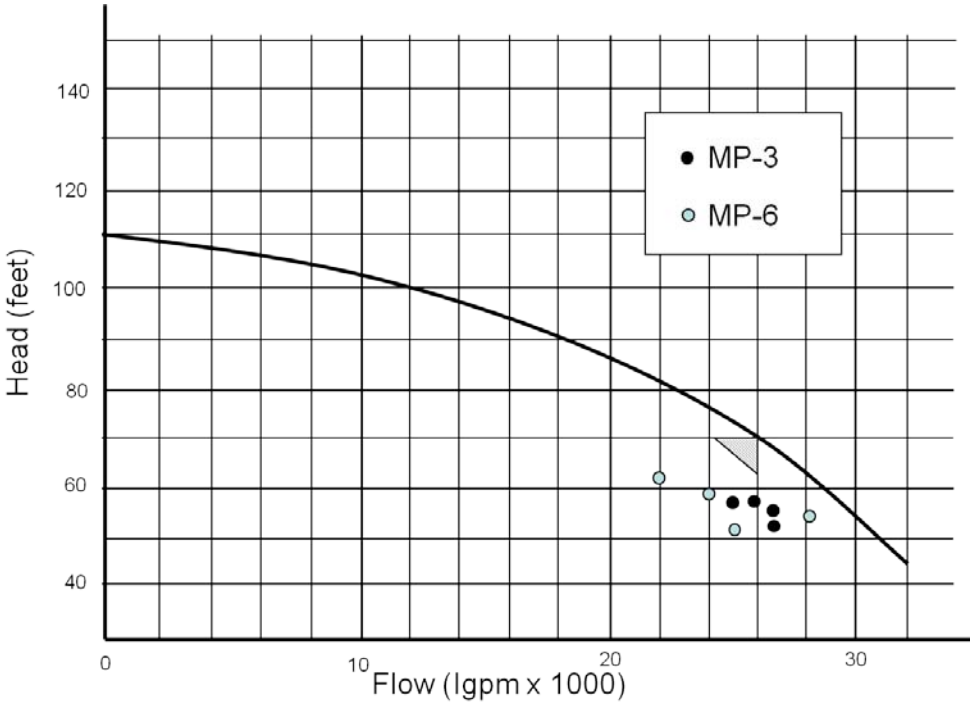

Exhibit 5: Pump performance test results for Pump MP-6 as compared to Pump MP-3

The test results for MP-6 were consistently below the original pump curve. The results suggest that there is a physical difference between the existing conditions and what was anticipated when the original pump curve was developed.

The results for pump MP-3 are included on the same plot. MP-3 is an identical pump to MP-6, as with MP-6 it does not have speed control and has an identical pump curve and very similar operational conditions. The test results for MP-3 are very similar to those of MP-6, falling below the original pump curve.

The most likely cause of the difference between reported and expected pump performance is the use of a smaller or less efficient impellor. The other logical possibility would be a reduction in motor speed, but there has been no reported change to the motors since their initial installation.

The actual results align with the expected head conditions, while the duty point from the original pump curve is not consistent with existing conditions. A change to the discharge piping would have changed the dynamic head, but it is believed the existing piping is the original piping and the heads would not have materially changed.

The rated flow as reported in the operating manuals for MP-6 and MP-3 is 188 ML/d (equivalent to 28,756 Igpm). It is apparent from the test results that the pumps would only be capable of pumping this rate under a high wet well condition.

The pump performance for MP-5 is plotted in Exhibit 6 for both high and low speeds, with flow units presented in the original units of US Gallons Per Minute (USgpm) and head in feet. High speed is with the pump running at 506 rpm, while low speed is at 450 rpm.

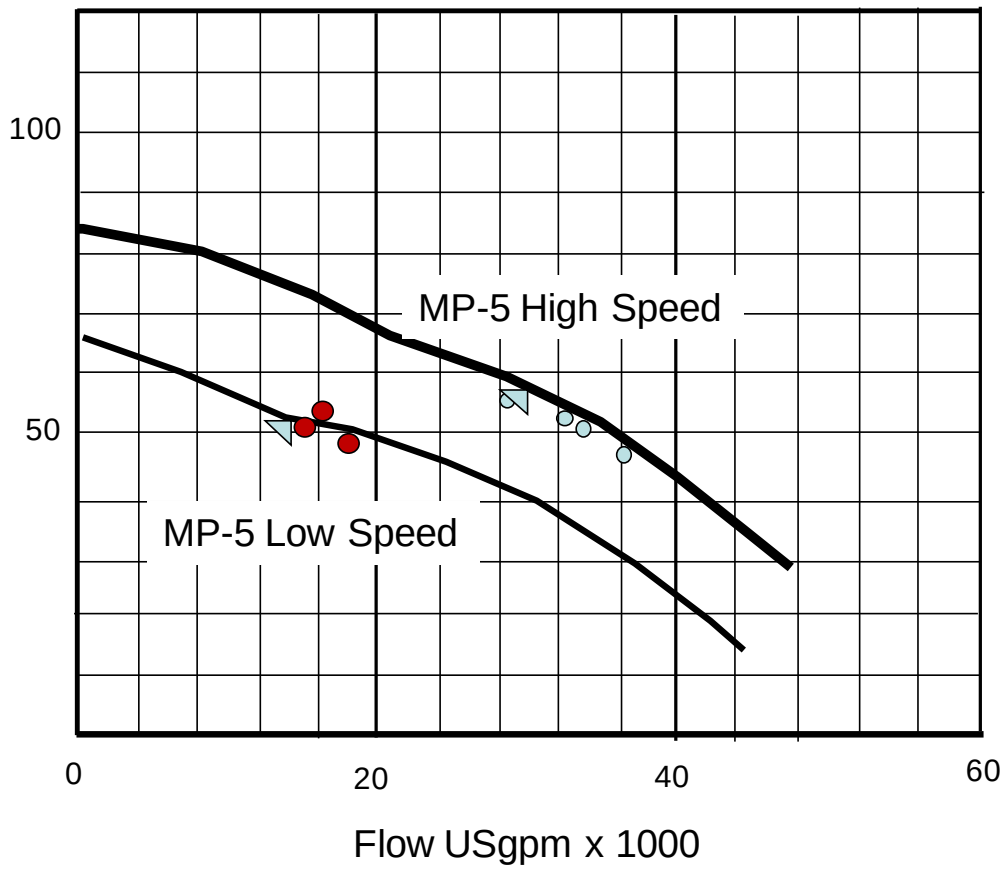

Exhibit 6: Pump performance test results for Pump MP-5, for High and Low Speed operation

The test results indicate that the actual performance is very close to the original pump curves, and unlike MP-6 and MP-3, the pumps are operating very close to their duty points.

The rated flows as reported in the operating manuals are 150 ML/d (27,500 USgpm) at low speed and 195 ML/d (35,800 USgpm) at high speed. From the test observations, MP-5 would be able to pump 195 ML/d under high wet well conditions.

The flow range under low speed was closer to 18,000 USgpm, which is about 98 ML/d, which is substantially less than the anticipated 150 ML/d. The source of the reported 150 ML/d is unknown, but it is evident it is over reported in the operating manual.

Pump efficiency lines from the original pump curve have been added to the curves in Exhibit 6.

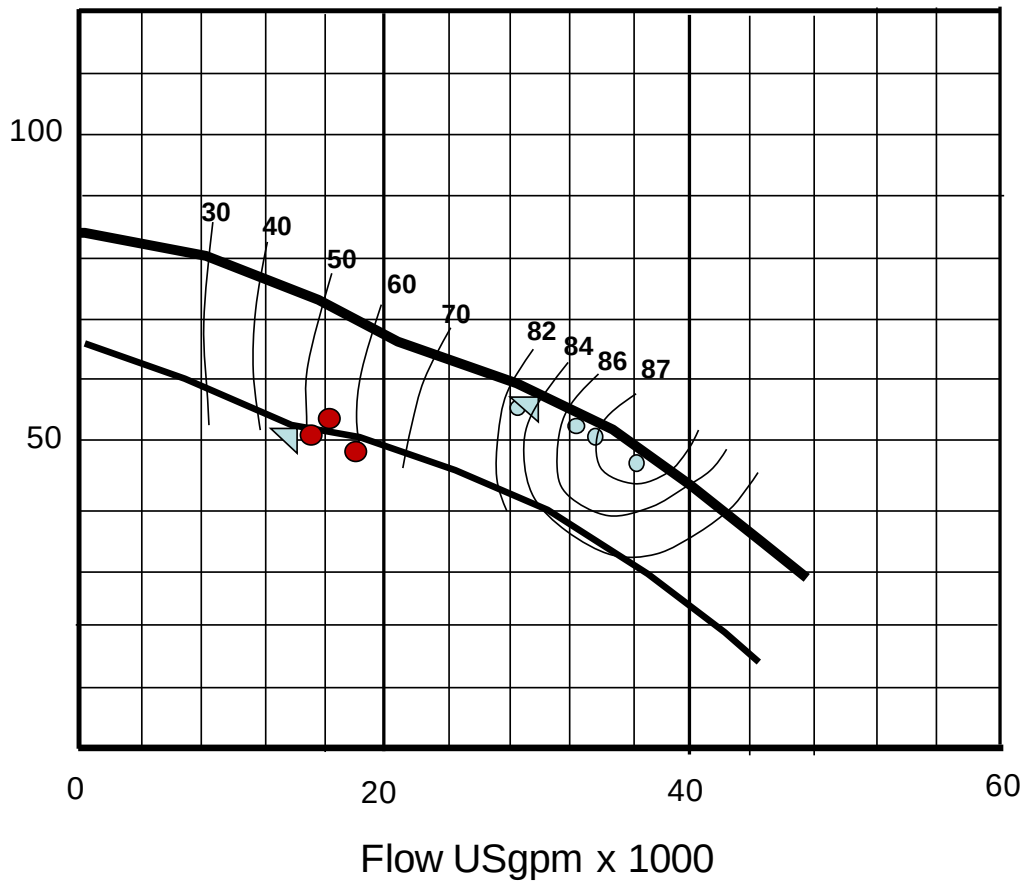

Exhibit 7: MP-5 Pump Curves with Efficiency lines

Pump efficiency for MP-5 is the highest when the pump is operating at high speed with a high wet well level. As the pump discharge decreases the efficiency drops off. At the low speed the efficiency would be expected to be low for operation of a centrifugal pump. The MP-5 original pump curve includes a statement "DO NOT OPERATE BELOW 78% EFF WITHOUT CONSULTING FACTORY" along with the project specific note that the pump is expected to be at 50% efficiency at low speed.

In addition, at the low speed the pump curve flattens out, which typically results in less stable flow. It has not been determined what the actual operating impacts of these factors are, but they are likely to contribute to less than optimal pump operations.

Inlet and Suction Test Findings

The main objective of the pump tests was to investigate the operation under the existing inlet configuration. Operational problem would support a recommendation for either further inlet condition testing and analysis, or modifications to the physical inlet to avoid the situation.

Inlet Configuration

The theoretical result of a two plane inlet transition is the introduction of swirl. Rotation in the same direction as the impellor rotation would increase pump flow while in the opposite

direction would reduce flow. Neither condition would be desirable because of uneven loading and flow distribution.

The test results for MP-6 do indicate results that are similar to the effect of swirl, since the pump performance curve falls below pump curve as it would with swirl and the deviation varies with the flow rate. This condition is unlikely and probably caused by different factors since MP-3 which does not have these inlet conditions exhibits the same effect. Similarly, if swirl effects were occurring they would also be evident on MP-5, but opposite in effect, which is not the case.

There was also concern the configuration, short suction pipe length and high velocities would cause instability and problems with pump performance. In addition to the hydraulic performance, vibration monitoring was used to assess the pump operation.

Vibration Test Results and Observations

Vibration testing can uncover a number of equipment and operational problems, including unbalance, misalignment, bearing problems, hydraulic forces and support system problems. The absence of vibration is normally an indication these conditions do not exist.

The vibration test results are summarized on the previously presented Tables 1 to 5. The vibration results did not indicate and excessive vibration problems for any of the pumps.

The test results are included in a letter report from Power and Mine, attached to this document. In summary, the vibration results indicated:

- Highest vibration of 0.161 in/sec was for pump MP-6 operating at the lowest wet well level (-16')
- Rotors are well balanced
- Good alignment between motor and pump
- No cavitation was evident from the vibration results

While some vibration was evident, it was classified as "satisfactory to good" based on ISO 10816 standard, and not indicative of installation problems.

Power and Mine has noted that additional monitoring equipment and assessment would be required to assess specific issues such as the onset of cavitation. Site personnel did observe an increase of vibration and noise potentially indicative of cavitation on MP-6 at low wet well levels when MP-6 and MP-5 were operated in parallel.

It should be noted that the vibration testing was intended to identify obvious problems specific to the inlet conditions assessment, and not a complete system assessment.

Suction Hydraulics

- Net Positive Suction Head –NPSHR is a characteristic specific to each pump and must be lower than the NPSHA, which is a characteristic of the system. The NPSHA should be significantly higher than the HPSHR to avoid operation problems with pumping. One of the objectives of the test was to collect data to confirm the NPSHA. The suction header is a complex shape with varied size and the interior condition and resulting head losses are not known which impact the degree of precisions in calculating the head losses.

Conclusions

The site testing did not identify any operational problems that could be associated with the existing inlet configuration. In the absence of pump performance problems, it is concluded that new pumps can be installed to replace the existing pumps without modification of the suction header or inlet piping.

The pump performance is however directly related to the pumping equipment, and there is no guarantee that different types of pumps will perform equal to the existing pumps under the same conditions. Therefore it is recommended that this test report be provided to potential pump supplier for their review and consideration prior to bidding on pump supply, allowing them an opportunity to evaluate the inlet configuration and confirm their equipment will provide satisfactory performance under the conditions.