CITY OF YORKTON
DIAGNOSTICS PROGRAM:

Microbiological Activity Assessment
of
Production Wells

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EXECUTIVE SUMMARY

The Sustainable Water Well Initiative (SWWI) was created in 1996 by the Prairie Farm Rehabilitation Administration (PFRA) to address concerns of declining well yield, water quality deterioration and reduced well lifespan. The intent of the SWWI is to investigate the various problems that are often experienced in water wells. As part of ongoing SWWI studies, the City of Yorkton expressed interest in working jointly with PFRA to conduct a microbiological assessment of their production wells.

Diagnostic testing was conducted at ten well sites by the City of Yorkton, from August, 1999 to March, 2000. The diagnostics procedures consisted of conducting a one-hour pump test at each well site to determine its specific capacity and collecting water samples for microbiological analysis. Microbiological testing was conducted by using Biological Activity Reaction Tests (BART™) to determine the presence and aggressivity of selected groups of bacteria that cause water well biofouling. The BART™s used for the microbiological testing of the water samples were the HAB-BART™ (heterotrophic aerobic bacteria), the IRB-BART™ (iron related bacteria), and the SRB-BART™ (sulphate reducing bacteria). Both the pump test and microbiological analysis data were collected and compiled by the City of Yorkton, and were then forwarded to PFRA for evaluation.

The diagnostics testing results indicate that the existing monitoring program and preventative maintenance procedures for the City of Yorkton are effective in maintaining the performance of the majority of the wells. Only 2 of the 10 wells tested had a specific capacity reduction of greater than 26 per cent from original. Most of the wells have experienced only a moderate decline in specific capacity and the biological aggressivity levels are usually observed to be medium to low. However, one anomaly is Well 11, which has highly aggressive levels of biological activity, but has actually experienced an increase in specific capacity since March, 1999. This dramatic increase in specific capacity in Well 11 may be attributed to rehabilitation work conducted in the spring of 1999, which has opened up new water pathways to the well, or perhaps there is an avenue of direct recharge to the well system from a surface water body.

Wells 1 and 12 have experienced declines of 40 and 60 per cent, respectively, from their original specific capacities, and have also recorded some of the highest biological activity. Therefore, it is recommended that well treatments, designed specifically to remove biological plugging material, be conducted at these two wells sites. Regular monitoring of all the wells should be conducted at least every six months to observe any losses in specific capacity or increases in biological activity, with the frequency adjusted depending on the results obtained for each well. Also, based on findings from previous SWWI studies, it is recommended that preventative maintenance procedures be applied before the specific capacity of a well has declined more than 20 per cent from original, or when the biological activity has increased by one order of magnitude, and a well treatment should be conducted before the specific capacity has declined more than 40 per cent or the biological activity has increased by two orders of magnitude.

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1.0 BACKGROUND

The deterioration of well yield and water quality is a concern to those who rely on water wells as their principal source of water. In view of this, the Sustainable Water Well Initiative (SWWI) was created in 1996 by the Prairie Farm Rehabilitation Administration (PFRA) to address concerns of declining well yield, water quality deterioration and reduced well lifespan. The intent of the SWWI is to investigate the various problems that are often experienced in water wells. However, this initiative has initially focussed on the microbiological aspects of water well deterioration and rehabilitation, since this aspect is still the least understood. As a result of SWWI studies to date, a better understanding of a water well biofouling is being obtained. As well, a new treatment process for biofouled wells, known as Ultra Acid-Base™ (UAB™), was developed by Droycon Bioconcepts Incorporated (DBI) of Regina, Saskatchewan, in conjunction with PFRA, and a joint venture arrangement was established to field test this treatment technology. The results of the various SWWI studies are available on the PFRA web site: www.agr.ca/pfra/water/swwie.htm.

1.1 Introduction

As part of ongoing SWWI studies, the City of Yorkton expressed interest in working jointly with PFRA to conduct a microbiological assessment of their wells. On August 5, 1999, a meeting was held between Jerry Cheshuk and Mike Buchholzer of the City of Yorkton, and Harry Rohde and Twyla Legault of the PFRA to set-up a diagnostics program that will investigate the presence and level of microbiological activity at each production well site. The methodology and results of this investigation are provided in this report, and the study area is outlined in Figure 1.

2.0 DIAGNOSTICS PROGRAM

Diagnostic testing was conducted at ten well sites by the City of Yorkton, from August, 1999 to March, 2000. The diagnostics procedures consisted of conducting a one-hour pump test at each well site to evaluate their performance characteristics and collecting water samples for microbiological analysis. The pump test and microbiological analysis data collected and compiled by the City of Yorkton was then submitted to PFRA for evaluation.

2.1 Pump Testing

One-hour pump tests were conducted on Wells 1, 2, 4, 5, 6, 7, 8, 9, 11 and 12, to determine their specific capacity. Wells 3 and 13 were not tested, since they are not in use, and Well 10 is a seasonal well and will be pump tested when it is put into production in the summer of 2000. During each pump test, the well is pumped at a constant rate and the water level in each well is recorded at regular time intervals. The pump test results are presented in Appendix A.

2.2 Microbiological Testing

The purpose of microbiological testing is to determine the degree of biological activity in the wells and surrounding aquifer. The microbiological testing was conducted by the City of Yorkton using Biological Activity Reaction Tests (BART™) to determine the presence and aggressivity of selected groups of bacteria that cause biofouling of the water well environment. The BART™s used for the microbiological testing of the water samples were the HAB-BART™ (heterotrophic aerobic bacteria), the IRB-BART™ (iron related bacteria), and the SRB-BART™ (sulphate reducing bacteria).

The BART™ system was developed by Droycon Bioconcepts Incorporated (DBI) and offers a simple method to detect the presence and aggressivity of nuisance bacteria that cause biofouling of water wells. Two forms of data are obtained by using this system: 1) the days of delay (DD) which is the time elapsed from the addition of water to the biodetectors until the initial reaction occurs and, 2) the reaction type (RX). The DD are used to determine the level of aggressivity of a bacteria group. The shorter the days of delay for a reaction to occur, the more aggressive the bacteria. The various reactions observed provide an indication of the types of bacteria present in the water sample (Cullimore, 1993). A summary of the data supplied by DBI, to determine the aggressivity levels of bacteria, is provided in Table 1 and a BART™ interpretation chart is provided in Appendix B.

Bacterial Aggressivity Level	Days to Initial Reaction (DD)				
	HAB- BART™	IRB- BART™	SRB- BART™	SLYM- BART™	DN- BART™
High	1 - 2	1 - 4	1 - 5	1 - 3	1 - 2
Medium	3 - 4	5 - 8	6 - 8	4 - 6	3 - 4
Low	5 - 10	9 - 10	9 - 10	7 - 10	5 - 10

Legend: High - greater than 10,000 colony-forming units per millilitre (cfu/ml)
Medium - 100 to 10,000 cfu/ml
Low - less than 100 cfu/ml

TABLE 1 Bacterial Agressivity Levels

2.2.1 Protocols for Microbiological Testing

The following is an outline of the recommended protocol for the microbiological testing of the City of Yorkton wells:

1. **Prior to collecting water samples for microbiological testing, those wells which are in regular use should be shut down for 24 hours.** This change in operation is intended to stress biofilms that have developed in the well and in the surrounding aquifer. It is anticipated that when the pumping resumes some of the stressed biofilms will shear off. This ensures that microorganisms which are bound in the biofilms can be collected for analysis.

2. **Those wells which are not in regular use should be pumped clean for some time and then shut down until the water in the well has returned to static level.** A well that sits stagnant for long periods of time can develop microbiological growth in the well column which is not representative of the microbial activity that is normally involved in well biofouling.

3. **Three water samples are be collected while the well is pumped at a constant rate.** One sample will be collected after 10 minutes of pumping, one after 30 minutes of pumping and one after 60 minutes of pumping. Samples must be collected in ***sterile*** containers. Sterile containers that hold 200 ml or more can be purchased from the local health unit or the Regina Health Lab. A new container must be used for each water sample. When collecting water samples it is important to keep the inside of the lid and container sterile.

4. **The water samples must be kept cool until testing begins.** In the field, the samples can be placed in a small cooler with ice. When the samples are returned to the lab they should be placed in a refrigerator until tested. If possible, the water samples should be placed in the biodetectors on the same day they are collected.

In this study, three BART™ tests were performed on each water sample collected, for a total of nine tests per well. The water samples were placed into the BART™ biodetectors on the sample collection date and were then examined once a day for ten consecutive days, with any observed reactions recorded on the data sheets provided by PFRA. The first examination of each activated BART™ occurred approximately 24 hours after the water sample was added to the biodetector, and this is considered Day 1 of the test. The second examination occurred 24 hours after the first examination, and these observations continue for ten days. Once the BART™ results for all the wells had been compiled by the City of Yorkton, the data was forwarded to PFRA for analysis.

3.0 PROJECT RESULTS

3.1 Specific Capacity Measurements

The pump test results from the City of Yorkton wells indicate that only 2 of the 10 wells tested have had a specific capacity reduction of more than 26 percent from original. The pump tests performed for this study could not always be conducted at the original pump test rate, so a direct comparison of specific capacities was not always possible. However, these results provide a general indication of the performance history of each well. A comparison of the specific capacity measurements for each well is shown in Table 2 and the historical specific capacity data is provided in Appendix A.

As shown in Table 2, Wells 1 and 12 have experienced the greatest decline in specific capacity, while Wells 8 and 11 have each experienced an increase from their original specific capacity. The majority of the wells are generally within 26 percent of original, as indicated in Table 2. The specific capacity measurements are presented as imperial gallons per minute per foot of drawdown (igpm/ft).

Well Number	Specific Capacity Measurements (igpm/ft)				
	Pumping Rate (igpm)	Original Specific Capacity	Pumping Rate (igpm)	Specific Capacity (1999/2000)	Percent of Original Specific Capacity
1	300	23.08 (1966)	200	13.51	58.5
2	300	34.80 (1957)	250	33.47	96.2
4	180	4.98 (1987)	87	3.95	79.3
5	198	18.00 (1992)	300	14.63	81.3
6	330	6.25 (1964)	300	6.10	97.6
7	225	38.59 (1967)	232	33.14	85.9
8	600	28.97 (1969)	600	30.26	104.5
9	750	55.72 (1976)	600	41.38	74.3
11	769	55.20 (1981)	800	216.8	393
12	800	41.64 (1987)	550	17.05	40.9

TABLE 2 Specific Capacity Comparisons

3.2 Microbiological Testing

The microbiological testing involved collecting water samples at 10, 30 and 60 minutes during a one-hour pump test conducted on each well. The BART™ biodetectors were used to determine the presence and aggressivity of heterotrophic aerobic bacteria (HAB), iron related bacteria (IRB) and sulphate-reducing bacteria (SRB) around each well. The BART™ results indicate the presence of biological activity in most of the wells tested, although the aggressivity levels vary in each well, as shown in Figures 2 to 4. Well 8 has the least amount of biological activity with no reaction observed in all but one of the nine water samples tested. Wells 4 and 5 generally showed low aggressivity levels, while Wells 6, 7 and 9 generally showed medium aggressivity levels. Wells 1 and 2 showed medium to high aggressivity levels, and Wells 11 and 12 revealed high aggessivity levels. The detailed BART™ results are provided in Appendix B.

The HAB aggressivity levels in the various wells are shown in Figure 2. The presence of HAB indicate that there can be problems such as slime formations, turbidity, taste and odor, corrosion, health risks and hygiene risks in the well. Where highly aggressive levels of HAB exist, additional testing is recommended to determine precisely the nature of the microbial problem. Other BART^{TM}s can be used to detect the specific types of bacteria present. Figure 2 indicates that aggressivity levels of the HAB are high in Well 12. Most of the other wells had medium to low aggressivity levels, while Wells 4, 5 and 8 did not detect the presence of hetrotrophic aerobic bacteria.

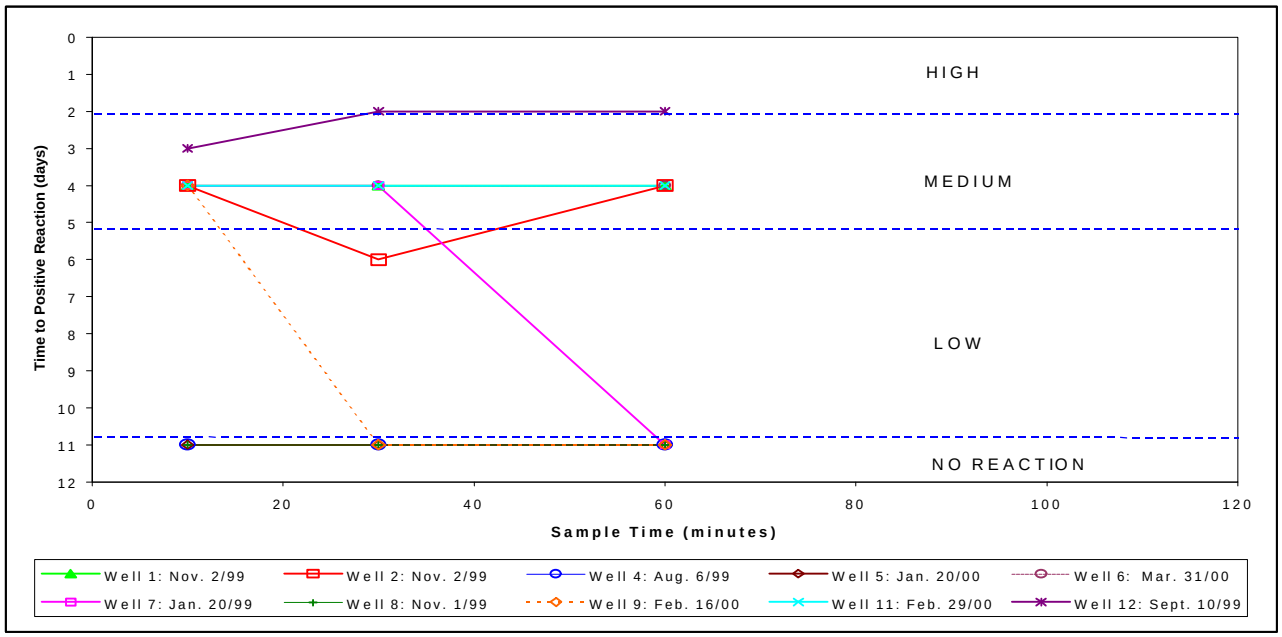

FIGURE 2 Aggressivity Levels of Hetrotrophic Aerobic Bacteria

The IRB aggressivity levels in the various wells are shown in Figure 3. The presence of IRB usually indicates "iron" problems in a well, which may include increased mineral scale or biological slimes.

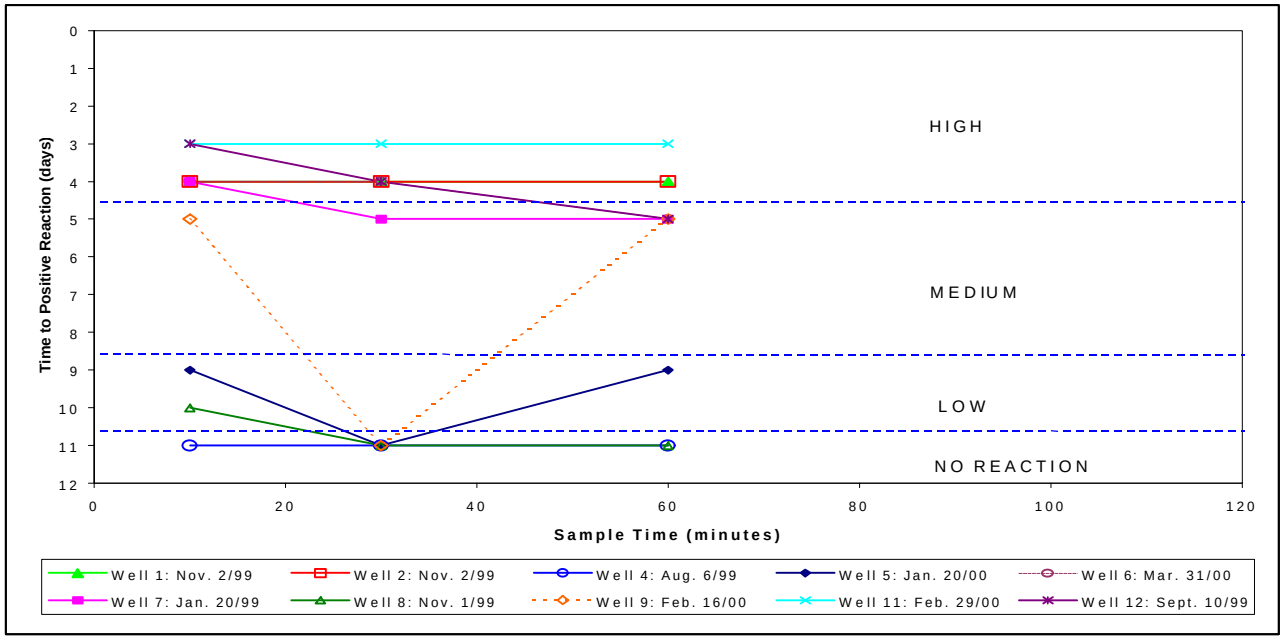

FIGURE 3 Aggressivity Levels of Iron Related Bacteria

The BART™ results indicate high IRB aggressivity levels in Wells 1, 2, 6, 11 and 12. Wells 7 and 9 have medium aggressivity levels, while Wells 4, 5 and 8 indicate low aggressivity or did not detect the presence of IRB. These results suggest that iron appears to be in sufficient supply as a nutrient to promote the growth of iron bacteria around most of the wells. Also, wells with higher aggressivity levels of IRB have an increased potential for biological plugging and mineral scale build-up.

The SRB aggressivity levels recorded in the various wells are shown in Figure 4. The SRB survive in environments where oxygen is not present, such as in sumps below the well screen or in non-producing areas of the screen or aquifer. They are also often found in wells that are not pumped frequently, since oxygen is depleted when a well sits idle allowing these bacteria to grow. Hydrogen sulphide gas is often released when SRBs are present, which produces a "rotten egg" odour. Wells 1, 11 and 12 generally have highly aggressive levels of SRB. Wells 2, 4, 6 and 9 have medium levels of aggressivity, while Wells 5, 7 and 8 indicate low aggressivity or did not detect the presence of SRB, as indicated in Figure 4.

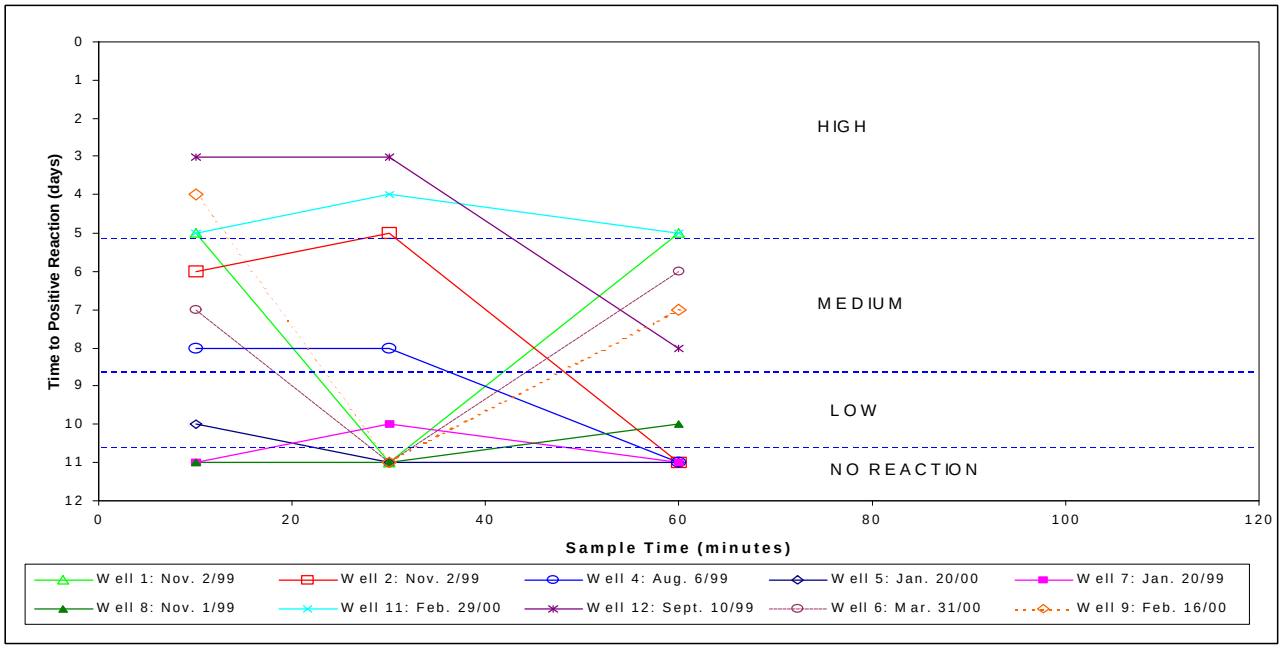

FIGURE 4 Aggressivity Levels of Sulphate Reducing Bacteria

4.0 DISCUSSION

The diagnostics testing program for the City of Yorkton wells revealed that 8 of the 10 wells tested had a specific capacity reduction of less than about 26 per cent from original. These wells vary from 8 to 43 years in age and are situated throughout the various well fields utilized by the City. The findings of this study suggest that the monitoring program and preventative maintenance procedures that are in place for the City of Yorkton have been effective in maintaining the performance of most of their wells. The results from the testing program also indicate that the wells in the West well field have the lowest levels of biological activity and have consequently recorded less losses in specific capacity. Although not conducted as part of this program, pump testing and biological testing should be performed on Wells 3, 10 and 13, to determine the condition of these wells.

The diagnostic testing results indicate that there appears to be a good correlation between the specific capacity measurements and the microbiological activity observed in each well. Wells 1 and 12, which have recorded high levels of biological activity, have also experienced the greatest decline in specific capacity, and Well 8, which has the lowest level of biological activity, has not experienced a decline in specific capacity. The only anomaly appears to be Well 11, which has high levels of biological activity, but has not experienced a reduction in specific capacity. Data supplied by the City of Yorkton indicates that since March, 1999, Well 11 has actually experienced a significant increase in specific capacity, from 57.9 igpm/ft to 216.8 igpm/ft. In discussion with Mike Buchholzer of the City of Yorkton, some redevelopment work had been conducted on Well 11 in the spring of 1999. The City should review the preventative maintenance procedures performed on Well 11 to determine if these could have contributed to the 375 per cent increase in specific capacity since March, 1999, or if other external factors, such as direct recharge from an overlying surface water body, may have contributed to this increase.

Although the City of Yorkton has been proactive in establishing and maintaining an effective well monitoring and preventative maintenance program, Wells 1 and 12 have experienced a reduction in original specific capacity of 40 and 60 per cent, respectively. Assuming that the monitoring and maintenance schedule has been fairly consistent for all the wells, this suggests that the standard approaches utilized for well maintenance and rehabilitation are not sufficient to maintain the production efficiencies for these two wells. Wells 1 and 12 also have some of the highest biological activity recorded in this study, and therefore, biological plugging of these wells and surrounding aquifers may have contributed to the significant decline in specific capacity at these sites. A well treatment designed specifically to remove biological plugging material should be incorporated into the maintenance and rehabilitation work performed at these two wells sites at the earliest opportunity. Findings from previous SWWI studies have shown that once a biofouled well has experienced a specific capacity decline of greater than 40 per cent, the ability to recover the lost specific capacity to original levels becomes extremely difficult (PFRA and DBI, 2000). Therefore, regular monitoring of all the wells should continue to observe any losses in specific capacity or increases in biological activity, and to signal when appropriate preventative maintenance procedures or well treatments would be required.

5.0 CONCLUSIONS

1. The diagnostics testing results indicate that the monitoring program and preventative maintenance procedures that are in place for the City of Yorkton have been effective in maintaining the performance of most of their wells Only 2 of the 10 wells tested had a specific capacity reduction of greater than 26 per cent from original.

2. The results of the pump testing and microbiological testing indicate that there appears to be a strong correlation between the specific capacity measurements and the microbiological activity observed in each well. Wells 1 and 12 have experienced the greatest decline in specific capacity and also have highly aggressive levels of biological activity.

3. Most of the wells have experienced only a moderate decline in specific capacity, with biological aggressivity levels usually observed to be medium to low. However, one anomaly is Well 11, which has highly aggressive levels of biological activity, but has actually experienced an increase in specific capacity since March, 1999. This dramatic increase in specific capacity in Well 11 may be attributed to rehabilitation work conducted in the spring of 1999, which has opened up new water pathways to the well, or perhaps there is an avenue of direct recharge to the well system from a surface water body.

4. The City of Yorkton water supply is obtained from four well fields located around the city. In terms of biological activity, the East and the Logan Flats well fields have higher aggressivity levels than the West and South well fields. The greatest decline in specific capacities has also generally been experienced in the East and Logan Flats well fields, which implies that there may be more frequent maintenance and rehabilitation work required at wells within these two well fields.

5. Well 8 has the least amount of biological activity with no reaction observed in all but one of the nine water samples tested. This implies that the well has been operated very efficiently and the maintenance procedures utilized are extremely effective in maintaining the yield of this well.

6.0 RECOMMENDATIONS

1. Well 11 has had a reported increase of 393% from its original specific capacity measured in 1981. This substantial increase was observed subsequent to redevelopment conducted on this well in the spring of 1999. Since such a dramatic increase is highly unusual, it is recommended that the well maintenance records be reviewed to establish the rehabilitation method utilized or to determine if any other changes may have caused this significant increase.

2. Wells 1 and 12 have experienced declines of 40 and 60 per cent, respectively, from their original specific capacities, and have also recorded some of the highest biological activity in this study. Therefore, it is recommended that well treatments designed specifically to remove biological plugging material should be incorporated into the maintenance and rehabilitation work performed at these three wells sites at the earliest opportunity.

3. It is recommended that regular monitoring of all the wells should continue to observe any losses in specific capacity or increases in biological activity. These tests should be conducted at least every six months, with the frequency adjusted depending on the results obtained for each well.

4. It is recommended that preventative maintenance procedures be applied before the specific capacity of a well has declined more than 20 per cent from original, or when the biological activity has increased by one order of magnitude.

5. Since previous SWWI studies have shown that once a biofouled well has experienced a specific capacity decline of greater than 40 per cent, the ability to recover the lost specific capacity to original levels becomes extremely difficult, it is recommended that a well treatment be conducted before the specific capacity has declined more than 40 per cent or the biological activity has increased by two orders of magnitude.

7.0 REFERENCES

Cullimore, R., 1993. *Practical Manual of Groundwater Microbiology*. Lewis Publishers, Chelsea, Michigan. 412 pp.

Keevill, B.,1999. *City of North Battleford Well Rehabilitation Project, Phase 1 Well Diagnostics(Biological and Chemical).* March 1999. Droycon Bioconcepts Incorporated, Regina, Saskatchewan.

Keevill, B., 1999. *City of North Battleford Well Rehabilitation Project, Phase 2 Well Rehabilitation (Ultra Acid-Base^{TM} Treatment).* December 1999. Droycon Bioconcepts Incorporated, Regina, Saskatchewan.

Keevill, B., 2000. *City of North Battleford Well Rehabilitation Project, Phase 3 Post-Treatment Monitoring.* March 2000. Droycon Bioconcepts Incorporated, Regina, Saskatchewan.

PFRA and DBI, 1997. *Development of Ultra Acid-Base (UAB^{TM}) Water Well Treatment Technology*. Prairie Farm Rehabilitation Administration and Droycon Bioconcepts Incorporated.

PFRA and DBI, 1998. *City of North Battleford Well 15, 1997 Field Test of UAB^{TM} Water Well Treatment Technology*. Prairie Farm Rehabilitation Administration and Droycon Bioconcepts Incorporated.

PFRA and DBI, 1999. *City of North Battleford Well Rehabilitation Project, Phase 1: Well Diagnostics Program*. June 1999. Prairie Farm Rehabilitation Administration and Droycon Bioconcepts Incorporated.

PFRA and DBI, 1999. *City of North Battleford Well Rehabilitation Project, Phase 2: Well Treatment Evaluation.* December 1999. Prairie Farm Rehabilitation Administration and Droycon Bioconcepts Incorporated.

PFRA and DBI, 2000. *City of North Battleford Well Rehabilitation Project, Phase 3: Post Treatment Monitoring.* April 2000. Prairie Farm Rehabilitation Administration and Droycon Bioconcepts Incorporated.