HORIZON SHORES MARINA: DESIGN AND OPERATION OF A SMALL REVERSE OSMOSIS PLANT

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ABSTRACT

Horizon Shores is a marina located approximately 50 km from Logan. The marina is not connected to town water and in the past the drinking water was provided by some treated rain water supplemented by significant volumes of potable water that had to be trucked in.

In November 2013, Walker Environmental designed and installed a GE pre-engineered reverse osmosis (RO) plant purchased from Water Equipment Plus. The water source for the RO is brackish ground water, drawn up through water spears which have been drilled into the sand to a depth of 4m. The feed water has an elevated salt level of between 800 and 1,000 ppm. Walker Environmental are now operating the unit for Horizon Shores and the RO is operating reliably to provide 27 kL/d of water to the marina. As trucking water in is expensive, the payback for the project will be less than 12 months.

Challenges overcome by Walker Engineering during project execution include:

- High iron levels in the feed water
- High silica levels in the feed water
- Increasing feed water salinity due to sea water intrusion

1.0 INTRODUCTION

Horizon Shores Marina consumes 20 to 30 kL per day of potable water. As the marina is not connected to the mains supply, the potable water had been trucked in at significant cost to the marina. Horizon Shores contacted Walker Environmental to investigate the use of bore water for this purpose.

Initial analysis of the bore water showed that the feed water salinity (or TDS – Total Dissolved Solids) was greater than the level recommended in the Australian Drinking Water Guidelines (ADWG). Walker Environmental therefore started work on a reverse osmosis solution to reduce the TDS level. This then highlighted some other concerns with the feed water in that the iron and silica levels, although within ADWG requirements, were likely to cause scaling and fouling in the RO unit.

Table 1: ***Feed water analysis vs Australian Drinking Water Guidelines***

Constituent	Horizon Shores Feed Water	Australian Drinking Water Guideline
Total Dissolved Solids	800 – 900 mg/L	< 600 mg/L
pH	6.6	6.5 to 8.5
Iron	2.6 to 4.7 mg/L	0.3 mg/L
Silica	50 mg/L	< 80 mg/L

2.0 DISCUSSION

2.1 Salinity Reduction

The plant uses reverse osmosis to reduce the salinity of the water. The salinity is measured as total dissolved solids (TDS) or conductivity.

The reverse osmosis process uses a membrane to separate out the dissolved solids or salts. The high pressure pump pushes most of the water through the membrane while the salts are left on the other side where they become concentrated. This creates two separate streams, the clean water stream or permeate and the concentrated waste stream or reject.

The diagram below shows the design case for the Horizon Shores plant. The diagonal line represents the membrane and the small arrows show the clean water being pushed through the membrane to be collected as permeate. The dots represent the dissolved salts which are mostly held back by the membrane and are concentrated up to be discharged as the reject stream.

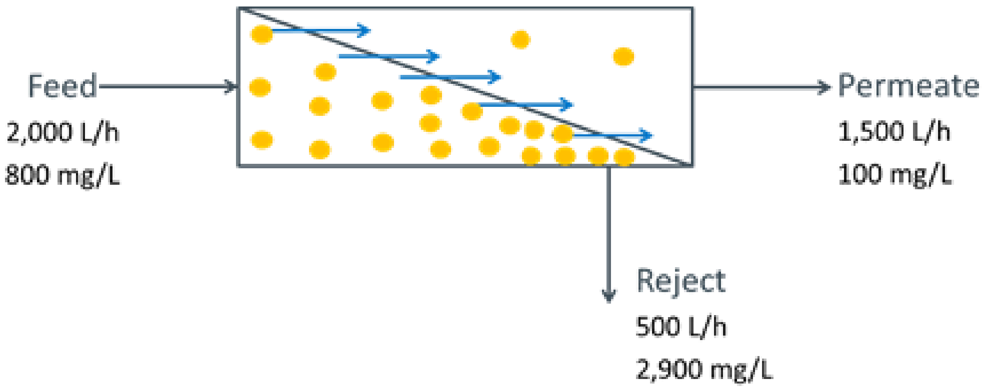

Figure 1: ***Reverse osmosis diagram***

2.2 Management of Increasing Feed Water Salinity

The original bore water analysis suggested that the feed water salinity was in the range of 800 to 900mg/L TDS. This is easily reduced by the RO to well below the ADWG recommended level of 500 mg/L and the selected pre-engineered plant was designed for a maximum feed TDS of 1,000mg/L.

After start-up it was found that the salinity of the bore water increased over time. Additional spears were installed which initially fixed the problem but eventually these bores also increased in salinity. It is now understood that as the spears draw the brackish water up they create a vacuum that is filled by sea water from the adjacent ocean inlet. Walker Environmental have now commenced a process of alternating which spears are in use to minimise the effect of salinity but have also been investigated other options with Water Equipment Plus. WE Plus ran a number of RO projections at increased TDS to predict the effect on the RO unit. Increasing feed TDS has two main effects on an RO. Firstly, the product water TDS will also increase and secondly, higher feed pressure will be required to push the saltier water through the membranes. The projections showed that the required product water quality was still being met and that there was actually more capacity in the feed pump than the standard design sheet had suggested.

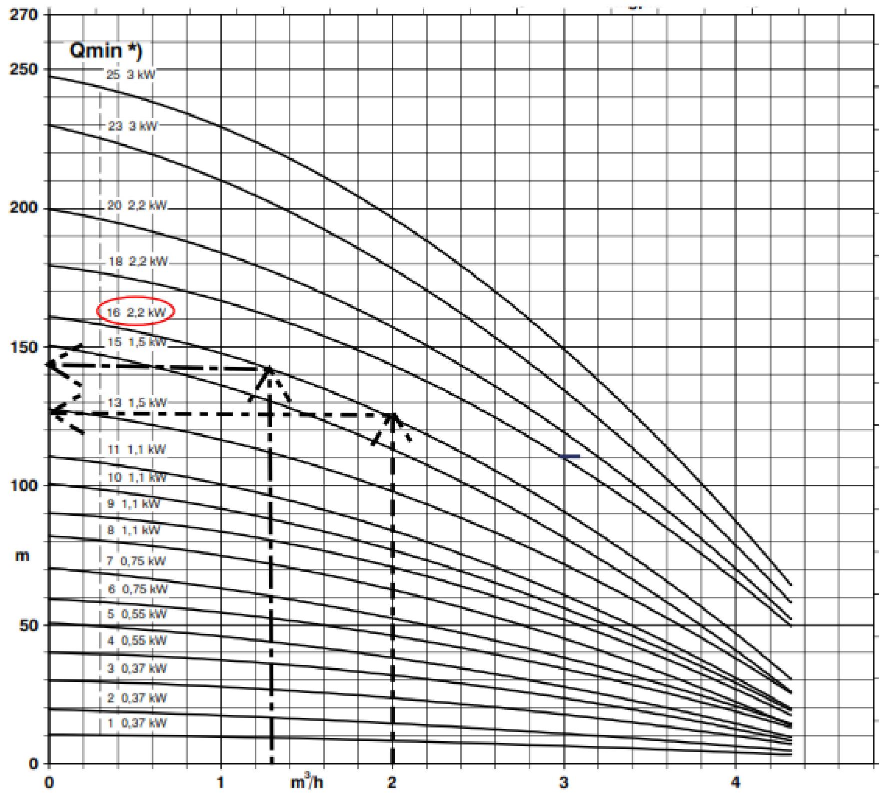

Figure 2: ***KSB Movitec V(S)2 curve (high pressure pump)***

For the design permeate flow of 1,500 L/h (which corresponds to 2000 L/h feed flow) the available pressure is approximately 127m (12.5 bar). Projections showed that a feedwater of 1,500 mg/L TDS could be treated without the need to reduce recovery or reduce flow rates.

The current usage is currently only approximately 20 kL/d so the plant is currently being operated at 1,000 L/h (which corresponds to 1,333 L/h feed flow rate). At this reduced flow, the pump can provide more feed pressure at up to 143m (14 bar). At this flow rate, the plant can easily treat feed water of 2,000ppm TDS.

2.3 Control of Iron Fouling

Iron exists in water in two common forms; ferrous (Fe^{2+}) and ferric (Fe^{3+}). Ferrous iron is soluble in water whereas ferric is a solid precipitate. In a bore water the iron starts in the soluble form but quickly changes to a solid precipitate as soon as it comes into contact with the air and is oxidised. Insoluble iron quickly fouls RO membranes, seen as the distinctive rust coloured sludge collected on the feed end of the membranes. The fouling prevents feed water flowing through the membrane, reducing output and increasing the feed pressure required.

The feed water requirement for the proposed GE skid was for it to contain less than 0.5ppm of iron, so iron removal methods were initially investigated. A common prevention method is to convert all the soluble ferrous to precipitated ferric then filter the solid out before the water reaches the RO unit. The conversion can be done by aerating the water or dosing with an oxidant such as chlorine. After chlorine dosing, an iron specific media filter such as DMI or Greensands can be used for better iron removal than a normal sand filter.

A downside of chlorine dosing is that the chlorine must then be removed (using SMBS dosing for example) before the RO unit as the membranes are quickly and irreversibly damaged by free chlorine. Another potential problem with the iron removal method is that it is very difficult to ensure that all ferrous iron has been converted and then removed before the RO. If any soluble ferrous iron remains, it could well convert inside the RO membranes creating the fouling after all.

The treatment method selected for Horizon Shores is to direct feed the water to the reverse osmosis unit. This prevents the water from being aerated and therefore keeps all the iron in the soluble form. In this case, the iron is completely rejected by the RO membranes and is collected in the concentrate or wastewater tank. Dow Filmtec recommends that this method can be used for iron concentrations up to 4ppm where the pH is maintained at less than 6 and the oxygen in the water is less than 0.5ppm. Anecdotal evidence from other operators within Australia suggested that plants could actually operate in the direct feed mode at much higher levels.

The Horizon Shores plant has been successfully operating in this mode with up to 4.7 ppm of iron in the feedwater for the past 6 months.

2.4 Control of Silica Scaling

As the dissolved solids are concentrated up on the reject side of the membrane, they can reach levels where they actually come out of the water to form solids or scales on the membrane surface. Scaling is typically seen on the last membranes on the plant where the concentrations are the highest and can lead to reduced flows and the requirement to clean the membranes more frequently.

In the feed water for Horizon Shores, the key scaling species of concern was silica. It is present in the feed water at approximately 50mg/L. At 75% recovery this would concentrate up to approximately 200 mg/L in the reject which is well above the saturation level of 96 mg/L (Byrne, 2002).

The decision was taken to dose a silica specific antiscalant to increase the maximum allowable silica concentration. Chemical antiscalants work in a number of ways. One key function is disrupting the growth of silica crystals so that the solids they form are softer, less regular and less able to adhere to the membrane surface. Another mechanism is to coat the individual silica particles giving them a slight surface charge. The particles are then repelled by each other and are unable to form larger particles that would eventually fall out of solution and are also repelled by the membrane surface, preventing them from sticking to it.

The antiscalant selected was Flocon 260, which increased the maximum allowable reject concentration to 350mg/L. The dark bar in Figure 3 shows that with Flocon 260 dosing, the reject concentration is now less than 60% of the maximum allowable, comfortably preventing silica scaling in the plant.

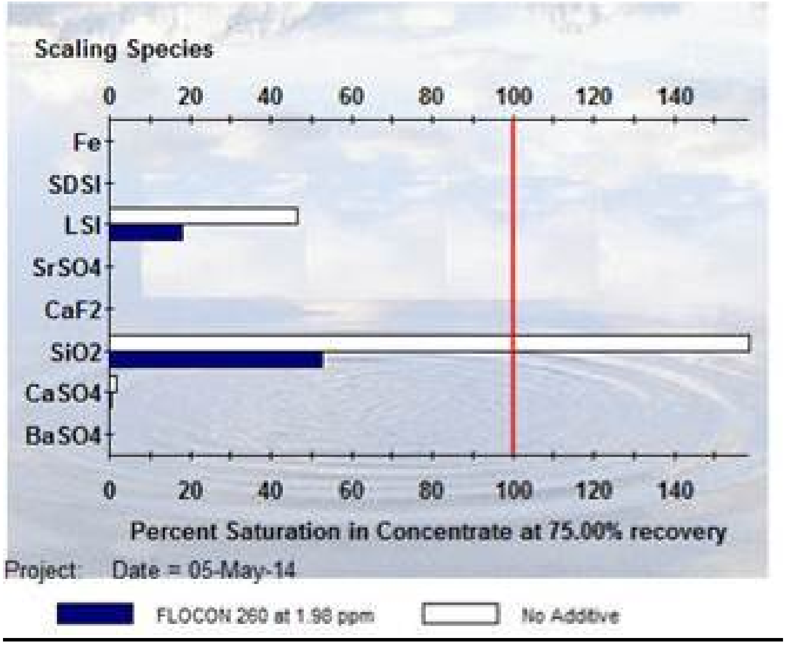

Figure 3: ***BWA Flocon 260 scaling projection***

3.0 CONCLUSION

The plant installed at Horizon Shores has been operating reliably for the past 6 months. The cost savings from no longer having to truck water in means that the payback period for the project will be less than 12 months.

The Horizon Shores experience shows that reverse osmosis is both a good technical solution and a financially attractive one for small communities and businesses such as marinas and resorts who do not have access to mains water.

The specific challenges of each individual water source demonstrates the benefit of working with experienced water treatment companies for the design and installation of even the smallest plant.

4.0 ACKNOWLEDGEMENTS

Thank you to the team at Walker Environmental who installed and comissioned the plant including:

- Fred and Chris who drilled the spears and connected them, then connected up the system and commissioned it.
- Lee and Mike who also worked on connecting up the unit and commissisioning it.
- Adam who managed the earthworks, running the pipelines and power to the unit.

A second thank you to Mike Walker, Managing Director of Walker Environmental Australia for allowing us to use this plant as a case study and for his assistance in preparing this paper.

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