Household-scale Water Supply from Surface Water Sources: Are Solar Pumps Appropriate Technology?

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Executive Summary

This paper investigates options for water supply to outstations using surface water sources. Solar pumps are considered as an alternative to the petrol pumps now commonly used, and treatment methods are also looked into. Special consideration is given to the circumstances and needs of outstation communities to try to find the most appropriate technology. An information sheet was developed to provide information on water supply to outstation coordinators and inhabitants. It is included as an appendix to this report.

Design standards and guidelines were found using a number of sources, including government literature and communication with outstations. Average daily demand is assumed to be between 250 and 400 litres per person per day. The pumping rate should be 2.25 times the daily demand, and the system should be able to store at least 2 times the average daily demand, and preferably 7 days’ demand. Normally when designing a water supply system, firefighting requirements would be taken into account but here they are neglected as that much storage is far too large to be provided economically.

There is a very wide range of pumps available, but only three types were considered in detail as part of this study. The two types of solar pumps looked at were the Mono range of helical rotor solar pumps and the Flojet range of electric diaphragm pumps, which can be directly coupled to solar panels. Onga pumps using Honda petrol motors were compared to the solar pumps because they are currently the most commonly used type of pump on outstations.

A cost comparison shows that the large Mono pumps are never more economical than the petrol pumps. The Flojet pumps are sometimes less expensive, but their application is limited. Comparing a number of pump characteristics such as reliability, serviceability, on-going cost, suitability for variable population and suitability for intermittent use showed that the petrol pumps are the most appropriate option and the Mono pumps the least appropriate.
Most outstations never treat and rarely test their water because it is very expensive and inconvenient for them. Small-scale treatment options and preventive approaches to water quality are discussed in response to these problems. Both off-line and in-line small sand filter units are considered in detail. Chlorine and ultraviolet disinfection are briefly discussed. Intake designs are discussed as a way to reduce the need for water treatment.

Petrol pumps were found to be the most appropriate technology for most outstations drawing water from surface sources. Small diaphragm pumps such as the Flojet range powered by solar panels may be an appropriate solution where demand is very limited. Small off-line sand filters could be a useful treatment technology for outstations, in situations where outstation residents recognise the need for water treatment.
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List of Acronyms

ABS      Australian Bureau of Statistics
ADWG     Australian Drinking Water Guidelines
AWRC     Australian Water Resources Council
CFU      Colony Forming Unit
DNR      Department of Natural Resources
NHMRC    National Health and Medical Research Council
SCRGSP   Steering Committee for the Review of Government Service Provision
UV       Ultraviolet
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1 Introduction

The aim of this study is to determine whether solar pumps are a viable alternative to the petrol pumps currently used for household-scale water supply in many outstations, in response to inquiries from remote communities. Social and environmental factors, as well as cost, are taken into account. Water quality issues and some treatment options are also discussed.

Water provision and quality is a very important consideration in Indigenous communities, as they have a much higher incidence of infectious diseases associated with poor sanitation than non-Indigenous communities. Intestinal and bacterial diseases, for instance, are 2.6 and 3 times higher respectively in Indigenous communities (SCRGSP, 2003).

Northern Queensland is unique in that surface water is more freely available than in other areas of northern Australia. This means that it is frequently used as a water source for outstations. Of around 96 small outstations in North Queensland, 49 communities, with a total population of around 500 are using water from surface sources (ABS, 2001). The rest of the small outstations rely on bores or rainwater. Elsewhere in northern Australia, these are the main sources of water (web ref. 3). Because of this prevalence in North Queensland of water supplies drawing on surface water, this study has focused on pumping systems suitable for surface water sources.

A further aim of this study was to produce an information sheet for outstations setting up water supply systems from surface water sources (Appendix A). It helps outstations to work out their needs in terms of head and flow, and then presents different pumping technologies that they can use. It also provides some information on water treatment in small communities.
2 Background

2.1 The Homelands Movement

Beginning with the 1970s Homelands Movement, there has been a movement of some Indigenous people away from towns and large settlements in an attempt to resume a close association with their traditional lands, and to move closer to a goal of self-determination. This has led to the development of hundreds of small settlements known as outstations or homelands across northern Australia. In Queensland, the Indigenous people began to have better access to their land as a result of the historic Koowarta (1982) and Mabo (1992) cases.

Many of these communities have extremely low populations. Queensland alone has 96 outstations with less than 50 people (ABS, 2001). Remoteness and diseconomies of scale make it very difficult to provide basic infrastructure such as roads, water or electricity to the people living on outstations (Grey-Gardner, 2003). As an example of this diseconomy of scale, it has been estimated that the capital cost per person of supply for community of 50 can be as much as 7 times the cost per person for a community of 10,000. The maintenance and operation costs are around 2.5 times as much (Queensland DNR, 2004).

Outstations are believed to have significant social value for Indigenous people (pers. comm., Gail Fisher). They provide a chance to get away from social problems such as unemployment, overcrowded living conditions, alcohol and crime that may be faced by Aborigines in cities and other centralised communities. Outstation life can also help teach young people about traditional culture and lifestyle.

It has also been found that Indigenous people living on homelands or outstations are less likely to suffer from lifestyle-related health problems such as diabetes, hypertension or obesity (McDermott et al., 1998). There is a ten year gap between the mean ages of death for residents of homelands and centralised communities – 58 and 48 years respectively.
2.2 Appropriate Technology

An important consideration in the selection of a water supply system for outstations is whether it will be *appropriate technology*. Can it be operated and maintained by the community members? Does it fit into the community lifestyle? It is important to avoid unnecessary complexity which may discourage use. Of course, it also must be economically feasible. Solar pumps are considered as a viable alternative to the diesel and petrol-powered pumps commonly used because they have been found to last longer and require less maintenance. This is despite the fact that the technology would be relatively unfamiliar and the initial cost of installation is usually high.

The concept of appropriate technology was developed for use in third-world countries, but it has applications to some communities here in Australia. Most technology aims to improve the quality of people’s lives. Whether it is appropriate depends on the social, cultural, economic and environmental context in which it is used. By the traditional definition, appropriate technology should maximise the use of renewable resources (Short & Thompson, 2003), but the Centre for Appropriate Technology places greater importance on the need for technology to fit into the social and economic context of the community. It should be able to be operated and maintained at a community level, and be as simple as possible. The greater the complexity of a system, the more potential there is for failure (Short & Thompson, 2003; Federal Race Discrimination Commissioner, 1994).

3 Design Standards & Policies

3.1 Demand

No national or Queensland state standard exists to specify water quantity provision to small Indigenous communities. In those with population of less than 50, demand has been recorded as between 2 and 250 L/p/d. However, in other Indigenous communities, demand has been as high as 2700 L/p/d. This suggests that the very low demand in the small communities could be due in part to restricted access to water. Very high demands may occur where taps are left on for dogs to drink from, or where
there are leaks in the system. Demand in non-Indigenous communities is close to 500 L/p/d, with much less variation (Yuen et al., 2001).

Literature from around Australia suggests water quantity requirements ranging from as little as 100 litres per person per day (Territory Health Services, 2001) to as much as 1000 L/p/d (Yuen et al., 2001). For this report and the accompanying information sheet it will be assumed that 250 to 400 L/p/d is a sufficient supply. These are the “basic” and “desirable” levels of supply given by the Northern Territory’s Environmental Health Standards for Remote Communities in the Northern Territory (2001). Some sources give average daily demand per household rather than per person (AWRC, 1989; WSAA, 1999). However, since outstation households often have more occupants than typical urban households, it is probably better to use a per person demand, multiplied by an estimate of the likely household population. Since outstation populations tend to be highly variable, an estimate at the higher end of the range of expected population should be used.

In most cases, elevated tanks are used to provide enough head (water pressure) at taps, although in some areas tanks may be placed on nearby hills, eliminating tank stand maintenance costs. These tanks would typically be no more than 6 m high. This is high enough as long as sufficiently large pipes are used in the house reticulation to minimise head losses (pers. comm., Rex Cummings). Friction losses in the pumping main also need to be taken into account. Systems pumping from surface water sources at outstations typically need to provide 10 to 20 m head.

Since the knowledge of demand in outstations is fairly poor, it would be useful to include water meters in new systems as they are installed. This would help to provide a better indication of usage to inform future decision-making.

### 3.2 Storage

The inclusion of adequate storage capacity in a water supply system is particularly important when using a solar pumping system, because the performance of the pumping system varies greatly with weather conditions. Water delivery will be greatly reduced in cloudy conditions.
Published guidelines for storage capacity vary widely. Storage capacity as low as 30 to 50% of the average daily demand is suggested where the supply is very reliable (WSAA, 1999). Solar pumps, however, are dependent on incoming radiation and thus do not provide a reliable supply. Storage of 2 to 7 days is recommended for systems relying on wind or solar pumps with no backup (AWRC, 1989). Given the variability of outstation populations, and possible delays to pump repairs due to remoteness, it seems prudent to include as much storage in the system as possible. Seven days or more storage is ideal.

Storage tanks can be at ground level or elevated. If there is no elevated storage in a system then a pressure pump will be required to provide water pressure for the distribution system. This is another mechanical device with associated energy demand and maintenance requirements, and capacity for failure, and so the use of a pressure pump should be avoided if possible. On the other hand, the provision of large elevated storage capacity is expensive. A possible compromise is to have a small elevated storage and a larger storage at ground level with a small transfer pump to fill the elevated storage.

The size of storage tanks that can be installed at outstations is further limited by the difficulty and expense of transport in remote areas with poor quality access roads.

### 3.3 Pumping Requirements

Water supply system design guidelines require the capacity of the pumping system to be greater than the average demand. This, in combination with the storage capacity, provides a margin of safety for periods when demand is greater than average, or for periods of pump failure. In the case of solar pumps, the greater pump capacity also compensates for the variation in pump performance due to weather conditions.

Pump capacity is not usually a limiting factor with fossil fuel pumps. Even the smallest pumps have a high transfer rate and can satisfy many days’ demand with a very short period of pumping. Increased demand can easily be met by increasing the period or frequency of pumping. Solar pumps, on the other hand, have a low transfer
rate which is further limited by weather conditions. Pump capacity is thus a very important criterion in selection of solar pumping systems.

As with storage, the required rate of pumping is generally expressed in guidelines as a multiple of average daily demand. For example Queensland’s Department of Natural Resources (2004) specifies that pump capacity should be equal to the Mean Day Maximum Month demand (MDMM), which can be estimated as 1.5 times average daily demand. South Australia’s Engineering & Water Supply Department (1986) suggests a pump capacity of 3 to 4 times average day demand. One local system designer consulted as part of this study (pers. comm., Andrew Feith) suggested that for remote area supplies pump capacity should be equal to the peak day demand, which is estimated as 2.25 times the average daily demand. Given the variability in both supply and demand on outstations using solar pumps it seems prudent to adopt this higher figure for pump capacity. It may be more cost-effective to improve reliability by increasing storage rather than increasing pump capacity, but this will depend on the economics of the particular situation.

3.4 Firefighting
DNR (2004) standards for firefighting supply are 15 L/s flow for 2 hours at 12 m minimum head. Since a fire is just as likely to occur at night when the pump is not working, a solar pumping system would need enough storage to account for all of this water. This would require 108 kL of storage just in case of fire. Considering the cost of the additional storage, it is unlikely to be feasible for outstation communities to make allowance for firefighting in the design of their household water supply systems. Other arrangements should be made for addressing firefighting requirements.

4 Solar Pumps
There are a number of types of solar pumps available in Australia, using several different pumping mechanisms. Broadly, these can be divided into centrifugal and positive displacement pumps. Although centrifugal pumps have many advantages, they are not well suited to solar power because they have a fixed minimum operating speed, below which no pumping occurs. So when the energy supplied to the pump
drops below a certain level, it stops pumping. This is a big problem with a variable energy source like solar or wind power. Positive displacement pumps, on the other hand, continue to provide water, but the flow rate is reduced as the incoming power drops (Kenna & Gillet, 1985).

There are three main types of positive displacement pumps. These are helical rotor, piston and diaphragm pumps. Helical rotors are reputed to be one of the most suitable mechanisms for solar pumping in remote areas, because they are more durable than piston or diaphragm pumps. Helical rotor pumps have been widely used on remote pastoral properties throughout Australia for many years, and are generally considered to be very reliable, with very limited maintenance requirements.

The most widely available helical rotor pumps are manufactured by Mono and Grundfos. Mono pumps were investigated in this study because comprehensive sizing and pricing information was available from a trusted local supplier.

Smaller solar pumping systems often use a diaphragm pumping mechanism. Submersible diaphragm pumps designed specifically for solar pumping systems are available. Shurflo is one brand of submersible diaphragm pumps. Pump suppliers contacted for this study considered these pumps to be far less reliable than helical rotor pumps. Small, inexpensive diaphragm pumps are also commonly used for other applications such as bilge pumps in boats, and for pressurising agricultural spraying systems. A small diaphragm pump in the Flojet range that has been used successfully in one outstation water supply known to CAT was included in this study for comparative purposes.

Solar pumping systems may be susceptible to damage by cyclones in Northern Australia, since their shape makes them likely to get blown away (pers. comm., Rex Cummings). If the wiring is not covered, it can be eaten by birds. Theft is also a problem that has arisen in the past since solar panels are viewed as a high-value item.

For the cost comparison, the maintenance costs of both types of pump were estimated at $50 per year based on product information from WD Moore & Co (web ref. 6).
4.1 Mono – a submersible helical rotor pump

The Mono range are marketed as solar pumps. The solar array, controller, wiring and other equipment are all included in the price in addition to the pump. They can provide a very wide range of head and flow rates. Mono pumps use a stainless steel helical rotor to lift water.

GPS tracking systems are available with some solar pumps to adjust the solar array to maximise its exposure to the sun. They are available with the Mono range and can increase performance by about 30%, however these were not considered as part of this study because they would make the system more complex and increase the number of potential problems.

The pumps have a very high capital cost, ranging from $4,000 to $10,000 for the ones analysed here. They have been found to be reliable, but if something goes wrong with them, they require expert repairs.

4.2 Flojet – A surface-mounted diaphragm pump

The Flojet pumps are electric diaphragm pumps which may be powered by direct connection to solar panels. The range also includes AC powered pumps which may be connected to a generator. This range was considered because a Flojet 2130-132 is being used at an outstation on Mornington Island in the Gulf of Carpentaria, and the residents have been pleased with its performance (pers. comm., Dennis Twine). Although it has broken down once, parts were easy to get and the repairs were able to be done by someone in the area. At this site the solar array provides electricity directly to the pump without passing through a controller or battery, reducing the complexity of the system.

The performance characteristics of this model are shown in Figure 1. This type of pump provides very low flow rates, only has about 3 m of suction lift and is non-submersible so its applications are definitely limited.
Including the cost of a 75 W solar panel, this model is not much more expensive than a petrol pump. The diaphragms need to be replaced regularly, so more maintenance is required for these pumps than for the Mono ones.

![Performance curve for the Flojet 2130-132 pump as used at Gunan Woonan (from web ref. 2)](image)

**Figure 1:** Performance curve for the Flojet 2130-132 pump as used at Gunan Woonan (from web ref. 2)

### 5 Fossil Fuel Pumps

In CAT’s experience, confirmed by consultations with outstation coordinators as part of this study, the pump most commonly used for outstation water supplies from surface water sources is the Onga 350 pump powered by a Honda GX160 petrol motor. This model is also known as a “firefighter” pump. Its performance characteristics are as shown in Figure 2. Often they are used as a “disposable technology,” which means they are purchased with grant money, they are not able to be maintained, and they are used until something goes wrong with them. If it is a simple problem they might be repaired, but otherwise they are just replaced.
The fuel consumption of the Honda motor used with this pump is approximately 1.67 L/hr (pers. comm., Nuleaf Horticulture & Irrigation Services; web ref. 1). This information was used to compare the costs of this pump and solar pumps in the next section.

Maintenance costs were calculated as a function of hours of use, but according to one outstation coordinator, the only maintenance on these pumps is changing the spark plugs at a cost of around $3.50 (pers. comm., Jaime Geddes).

Misuse of this type of pump has been a problem in the past (pers. comm., Bob Coakley). Some communities have used the wrong type of fuel or neglected to change the oil or perform other regular maintenance. There have also been other instances of damage such as dust getting into the machinery or the pulley breaking. The oldest pump of this type at Kowanyama is approaching 4 years and is almost ready to be replaced (pers. comm., Bob Coakley).
6 Comparison of Technologies

The available technology was reviewed and compared both in terms of cost and in terms of appropriateness to use in small remote communities.

6.1 Cost Comparison

6.1.1 Variables

For the cost comparison, a range of Mono and Flojet pumps were compared to the commonly used Onga “Firefighter.” The variables were population size, average daily demand, analysis period, discounting, the lifetime of an Onga petrol pump and the required pumping rate.

The difference in cost was considered in populations of 3, 6, 13, 25 and 35. From speaking to people at outstations, it seems that it’s probably best to design for stand-alone systems for each home. This means that the analyses with 3 and 6 people are probably the most relevant.

Two levels of demand were used in the analysis. 250 L/p/d is the Northern Territory Government’s (2001) basic level of supply, while 400 L/p/d is the desirable level of supply. These values are based on the AWRC (1989) guidelines.

The solar pumps are reported to last longer than petrol or diesel ones. WD Moore & Co. (web ref. 6) gives a range of 7 to 10 years as typical. 8 years was used here as the lifetime of a solar pump, with the first analysis being done over this time. The panels, on the other hand, last much longer. They are usually under warranty for 20 years, but may last considerably longer. The 24-year analysis is based on the solar array lasting 24 years, with the pump being replaced twice during this time.

Future payments are discounted in most economic analyses as part of an assumption that it will be easier to make the payment in the future than at the present. However, many Aboriginal communities receive grants for major works but little on-going funding. From their perspective, it might be preferable to choose a system with a large upfront cost which can be paid for externally rather than a relatively inexpensive
system that brings regular fuel and maintenance costs which the community will have to pay. Analysing the pumping systems without discounting is an attempt to take this preference into account. Where discounting was considered, a rate of 7% was used.

When the Onga pump has a life of 4 years, we assume it is being reasonably well maintained. Maintenance costs are incurred, but it lasts a fairly long time and stays at the fuel efficiency given by the manufacturer for its life. When it has a life of 2 years (the length of the Honda engine’s warranty), it functions as “disposable technology.” It is not properly maintained, but it will be easy to replace after it breaks down. No maintenance costs are assumed in this case, but fuel efficiency is reduced to 2L/hr instead of 1.67 L/hr.

The chosen pumping rate was $2.25 \times$ the average daily demand, or peak day demand. However, some literature recommended that the mean day maximum month demand, or $1.5 \times$ average daily demand, be used (Queensland DNR, 2004), so the analyses were also done using this delivery rate. Since the solar pumps are sized based on the required flow rate, it was believed that this could make solar pumps more competitive with petrol pumps.

All machinery was assumed to be useless at the end of its life, so salvage costs were neglected in the analyses. Installation costs and the cost of tanks and reticulation were assumed to be the same for solar and petrol pumps, and so were neglected in the analyses. For all the analyses, it was assumed that the pump was providing around 11 metres of head. This is a typical situation where water is being delivered from a stream, billabong or shallow well to an elevated storage.

6.1.2 Results

The only time that solar pumps are competitive with petrol pumps in an 8-year analysis is for very small supplies where the Flojet pumps are used instead of Mono. Figures 3-7 summarise the results of the 8-year present value cost analyses on solar and petrol pumps by showing the cost of petrol and solar systems as a function of daily flow required. In each graph, the cluster of points at the bottom left represents the Flojet pumps, and all the others are in the Mono range. There is no economy of
scale for solar pumps in such small communities because more solar panels are needed to provide power to pump more water, and solar panels are very expensive. This causes the step-wise increase in cost of solar pumps with demand.

The Flojet pumps are less expensive than the petrol pumps in most of the analyses where the demand is small. Even where petrol pumps are less expensive, there is a difference of less than 10%. This is small enough to be overlooked if the outstation has a strong bias against on-going costs or if they have a preference for a renewable energy source. Where the demand is high, though, the petrol pumps are less expensive than solar.

Figure 3: Present value of total costs over 8 years – Petrol pumps are expected to last 4 years and a 7% discount rate is used.
Figure 4: Present value of total costs over 8 years – Petrol pumps are expected to last 4 years and no discounting is used.

Figure 5: Present value of total costs over 8 years – Petrol pumps are expected to last 2 years and a 7% discount rate is used
Figure 6: Present value of total costs over 8 years – Petrol pumps are expected to last 2 years and no discounting is used.

Over the 24-year analyses the solar pumps become more competitive with petrol pumps. However, this is longer than many outstations have even been in place, and communities may be (justifiably) reluctant to make a decision based on such a long-term analysis.

A study comparing wind, solar and diesel powered pumping systems (Hammad, 1995) found solar systems to be much more cost-effective than diesel ones. The results of this study were expected to be similar, but in fact they show petrol pumping to be less expensive than solar in many cases. This may be due to the difference in scale of the water supplies. While pumps in this study supply a few thousand litres per day at most, the systems in Hammad’s study were supplying an average of 56 kL per day, at much higher head. However, it is also likely that a major difference is that Hammad’s study compared diesel to solar, while this one compared petrol to solar, and petrol systems are much cheaper, if less reliable, than diesel systems (pers. comm., Rex Cummings).
6.2 Appropriateness Comparison

The pumps need to be assessed for their appropriateness as well as cost. Some information on appropriateness criteria has been gathered by speaking to suppliers and outstation coordinators. The circumstances and needs of outstations affect the choice of appropriate technology. These choices may be very different from those of people living in cities and towns.

6.2.1 Criteria

Outstations are usually very remote, and the roads to them are quite bad. In tropical areas they may be inaccessible during the wet season. This makes it difficult to bring in machinery to install or maintain large systems.

They receive grants for infrastructure, but little on-going support, so they can’t afford high regular costs for maintenance. This creates a bias in these communities towards systems where as much of the cost as possible is upfront, with minimum on-going costs.

Reliability and serviceability are very important to outstations because in almost all cases there is no access to specialist skills. For this reason, technology which has proven reliable in the past or which is easy to repair would be favoured by outstations. A recent survey (Lloyd et al., 2000) showed that reliability was of much greater concern than environmental considerations to Indigenous communities.

They have very small populations, but there may be more than twice as many occupants for special occasions, or just over the weekend. A water supply system should be able to cope with this increase in demand, either by being able to pump at a high rate or by having lots of storage space.

It is not uncommon for outstations to only be inhabited part-time. In some cases this might be because the occupants only spend the weekends there, or it could be that it is inaccessible in the wet season. In either case, the water supply system should not need regular attention.
6.2.2 Discussion

Petrol pumps are more serviceable than solar ones because the mechanisms they use are very common. Many people in remote areas have skills and experience in maintaining small fossil fuel engines.

To a large extent, the pump’s reliability and appropriateness for intermittent usage depend on the people operating it. In the case of petrol pumps, they are likely to break down if they are never maintained or if the wrong fuel is used, so it could be said that they are less reliable in these situations. In terms of seasonal use, both petrol and electric diaphragm pumps need to be kept out of the water. If people leave an outstation for the wet season and don’t move the pump inside or to higher ground, it will be washed away or drowned. Similarly, the installation of a solar pumping system will impact on its reliability. If the pumps are well taken care of, they are all appropriate for intermittent usage. The larger solar pumps are more reliable than the Flojet pumps, which in turn are more reliable that the petrol ones. Large solar pumping systems have been found to be reliable in the past (Lloyd et al., 2000).

The solar pumps are considered less appropriate for highly variable populations because of the limit on their supply level. If a solar pumping system is designed to supply 6 people and the population increases to 15 for a week or two, it may not be able to deliver enough water. A petrol pump, on the other hand, could just be operated more often if necessary.

If firefighting requirements are neglected in choosing storage, as suggested earlier in this report, petrol pumps would probably provide more protection against fire than solar ones. This is because they can pump at such a high flow rate at any time of day. Another advantage to using the petrol pumps is that the same model pump is used at most of the outstations in an area. This means that old, discarded pumps can be used for parts if an operational one breaks down.

One situation in which a solar pump would be more appropriate than a petrol pump is a spring or shallow well. These water sources take time to replenish, so a petrol pump
could quickly pump them dry, as has been the case at some outstations in the past (pers. comm., Bob Coakley). This could cause damage to the pumping mechanism. Solar pumps are much slower, so would allow more time for water to seep back into the well or spring.

In many cases, particularly for larger outstations, the petrol pumps are preferable to solar pumps. They are inexpensive, easy to transport, reasonably reliable, have low on-going costs, can usually be serviced by someone in the area and provide very high flow.

7 Water Quality & Treatment

Surface waters tend to have water quality characteristics different to those of groundwater, and in particular are more prone to microbiological contamination. Other possible problems include turbidity, colour, hardness and algae. Quality may also vary significantly throughout the year (AWRC, 1989).

7.1 Testing

The NHMRC (2004) recommends weekly testing of water supplies for small communities (under 1000 people). However, testing on most outstations is actually only done 2 or 3 times each year, if at all (pers. comm., Bob Coakley). The NHMRC also makes the point that it is more effective to test regularly for a small range of key features than to occasionally test comprehensively. The features considered essential to test for are microbiological characteristics, pH, turbidity and chlorination residual where chlorine is used for disinfection. Onsite testing is available for the latter three characteristics, but a water sample has to be sent to a city laboratory to test microbiological quality. It has to be kept chilled and arrive within 24 hours to give a reliable result, constraints which make regular testing very difficult for people in the more remote areas.

One type of onsite test is available for *E. coli*, but it returns a simple presence/absence answer rather than an indication of the number of CFUs in the sample (web ref. 7). Using a test like this on untreated water is clearly unlikely to return a valuable result, as surface water is almost guaranteed to contain faecal coliforms. If the water is being
treated, however, using this test would be more valid, as it could give an indication of the performance of the treatment technology.

In the NHMRC’s framework for water quality, which is included in the 2004 Australian Drinking Water Guidelines, it recommends that small communities adopt a preventive approach to water supply management so that testing is less necessary. This approach entails protecting the water source and transmission lines to prevent entry of pathogens. Regular monitoring of the area is necessary. Important things to consider are keeping animals out of the water source and catchment and ensuring that human or animal effluent does not enter the water source.

It may also be helpful to avoid using the water source at certain times of the year. The most important of these would be the dry season if the water source becomes stagnant during that time, and immediately after the wet season’s first big rains as the runoff from these events will probably be carrying more contamination than at other times of the year (pers. comm., Allan Dick & Eddie Bobongie).

Conversation with outstation coordinators and occupants has indicated that they are aware of seasonal quality issues and the importance of protecting the source water (pers. comm., Jay Burchill & Glenda Woibo; pers. comm., Bob Coakley). In many outstations, a preventive approach is being implemented, although it may not be called that.

**7.2 Treatment**

Currently, most outstations don’t treat their water supplies (pers. comm., Bob Coakley & Jaime Geddes). In some cases it may not be necessary, because the water quality is good, like around the community of Wujal Wujal north of Cairns (pers. comm., Jaime Geddes; pers. comm., Jay Burchill & Glenda Woibo). In others, such as Kowanyama on the west coast of the Cape York Peninsula, there have been instances of children getting sick from drinking the water at certain times of the year (pers. comm., Bob Coakley). Since this variation exists, it is necessary to assess the risks that the water source may pose to each outstation individually.
7.2.1 Settlement

The water may be passed through settlement tanks or horizontal roughing filters to remove sediment (Oakley, 2003). Horizontal roughing filters use gravel to remove sediment from a horizontal stream of water. In settlement tanks, the sediment just settles out of a similar horizontal flow. Horizontal roughing filters are more appropriate where the velocity is high, or where the water has very high levels of suspended solids. They are similar to sand filters in that they can become clogged with sediment, and they add to the complexity of the water supply system.

7.2.2 Filtration

7.2.2.1 Sand

Small sand filters are a simple technology for treating water at a rate of 100-200 L/hour per m² of area. They may be used to improve very poor quality water to a stage where it can be used for non-potable uses, or it can be used to make reasonably clean water, such as rainwater or borewater, safe for drinking.

They improve quality by two mechanisms, filtration and biological predation. Filtration removes sediment, and may remove some pathogens in the process. Biological predation occurs because bacteria colonise the sand filter which then eat other bacteria and pathogens in the water coming through. It is important to maintain the level of water in the filter to keep these beneficial bacteria alive (Oakley, 2003).

These slow sand filters can be made on a very small scale. The example shown in Figure 7 can be manufactured for around $300 each, providing that several of them are being made (Oakley, 2003). It is also possible to make similar filters using concrete casing which are less susceptible to contamination because the plastic piping is encased in concrete (web ref. 5).
The filter shown is an off-line filter, however in-line filters with storage can be used instead. They are much more convenient for communities, since flow through sand filters is quite slow, but they also make the system more complicated. Constant head is required on the upstream side of the filter, and there are minimum head requirements at the tap also. This means that elevated storage would probably be needed both before and after the filter, but the filter itself needs to be on the ground so that it is easily accessible for maintenance. So the use of an in-line sand filter would require more storage, and probably a transfer pump after the filter.

Off-line filters have the additional advantage that they could be used seasonally at outstations where the water quality is only poor at certain times of year. It has been
suggested, however, that some communities would be reluctant to use them because they have to be manually operated and are perceived as a primitive technology (pers. comm., Robyn Grey-Gardner).

Over time, the filters can become clogged but cleaning them is fairly simple. The top 25 to 50 mm of sand should be stirred up. This will suspend all the trapped material in the standing water on top of the filter. The water can then be scooped off with a bucket, and the filter can be used again, although it will take a week or two for the bacteria to recover.

7.2.2.2 Other Filters
Other filters available, such as carbon, ceramic or spun poly filters, are usually cartridge systems. The cartridges have to be cleaned or replaced regularly, adding to the complexity of the system. Where the cartridges have to be replaced, it also increases the on-going costs considerably. These filters are generally quite effective at removing contaminants, but the majority of them are designed for “polishing” already treated water. They would quickly clog up and need replacing if used for filtering surface water, which typically has high sediment loading.

7.2.3 Disinfection
Chlorine or UV disinfection is used at some outstations to treat the water supply. It should be noted that neither of these treatments is very effective if the water has high levels of turbidity, so filtering is often required before disinfection anyway.

Chlorination is suitable to rainwater tanks, or those filled by a fossil fuel pump, that are filled, drained and filled again. This method is effective in killing bacteria, but it has the disadvantages that the water can’t be used for 24 hours after dosing, and that people often don’t like the taste so they just drink untreated water instead.

Point-of use UV treatment doesn’t draw very much power, but it does require a reliable supply, which isn’t ideal on outstations which may only use their generator every now and then. It also is unpopular with some people because it makes the water
warm, and therefore less palatable. Testing is required to make sure that it is working, and it also has the disadvantage that it has no disinfection residuals, and therefore is not effective for a prolonged time.

### 7.2.4 Dual Supply Systems

Another option for addressing the water quality constraints of surface waters is the use of dual supply systems. Untreated river or bore water may be supplied for non-potable uses, and either rainwater or treated water used for drinking and cooking. This greatly reduces the quantity of high-quality water required, but also creates the risk of people drinking water that is not intended for potable consumption. Where residents have a clear understanding of their water supply system this is certainly an option worth exploring.

### 8 Intake Design

When drawing water from surface sources, organic debris and high turbidity may be present in the water. In general, pumps are more efficient and less likely to break down when they can pump cleaner water. In addition to being harmful for pumps, these materials shield pathogens and take up disinfectant during treatment, so their removal makes treatment more effective. A good intake design can work to reduce the need for treatment, as well as protecting the pump.

The picture in Figure 8 is of a filter screen, which can be attached to the intake of a submersible pump or the end of a surface system’s intake line. The screen shown has 0.5 mm slots, which will remove organic debris and some sand, but will not remove smaller particles such as silt, clay or pathogens.
Where the source water is in a sandy area, the filter screen may be buried, as shown in Figure 9. It has been surrounded by coarse gravel to keep the sand out of the screen. A system like this one would be much more effective in improving water quality because the water is filtered by the sandy riverbed in addition to the filter screen.
Intake design can be a very important part of setting up a water supply system, but it is not covered in much detail as part of this study. Research and personal communications indicate that it is very site-specific, so it is difficult to make general recommendations.

9 Conclusions

The results of this study indicate that the use of large, complicated solar pumping systems is not yet feasible for outstations. Smaller, less complicated systems, on the other hand, offer a promising alternative to petrol pumps. Flojet pumps powered by solar panels should definitely be considered as an option by outstations. For a large number of outstations, however, the petrol pumps currently being used are the most appropriate of the options looked at in this study.

Small sand filters can be used to improve the water quality at a low cost. Some maintenance is required, but it can easily be done by people at the outstations or nearby communities. The filters are also easy and inexpensive to construct. Off-line filters are much simpler than in-line ones, but people may not be willing to use them. This technology appears appropriate, and is worth further investigation through field trials.
10 References


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**Personal Communications**

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Alan Dick and Eddie Bobongie, Tropical Public Health Unit, Queensland Health

Rex Cummings, Pumping, Irrigation and Machinery Services Mareeba

Robyn Grey-Gardner, Centre for Appropriate Technology Alice Springs

Nuleaf Horticulture & Irrigation Services Cairns (Onga pump suppliers)

Peter Fisher, Buru community member

Jay Burchill and Glenda Woibo, Buru community members
Appendix A: Design Guidelines for Household-scale Water Supply Systems from Surface Water Sources