2008 Water Use Analysis and Options Evaluation

Introduction

This report has three parts. The first part is a new analysis of water use by La Mesa Water Cooperative member/customers to provide a basis for estimates of future operation. The second is an evaluation for the timing of a new well. The third is an investigation of how water from Well #3 might be used to augment our capabilities.

1. How Much Water Do We Use?

Water use in the LMWC service area is highly seasonal. Summertime usage is two to three times that in the winter. Figure 1 shows water use during the 21st century. The line shows the average for the years considered and the points are the data for the individual months. June is apparently the highest use month. That lends credence to the idea that much of our water use is for landscape plants, because June is generally the hottest and driest month of the year. Note that June 2001 is an all-time high use month. However, note also that in 2003, July was the high use month and that, in 2005, June, July and August were nearly equal. Appendix A to this report contains the detailed information depicted in Figure 1. The average water use depicted here is about 4% less than that last calculated.

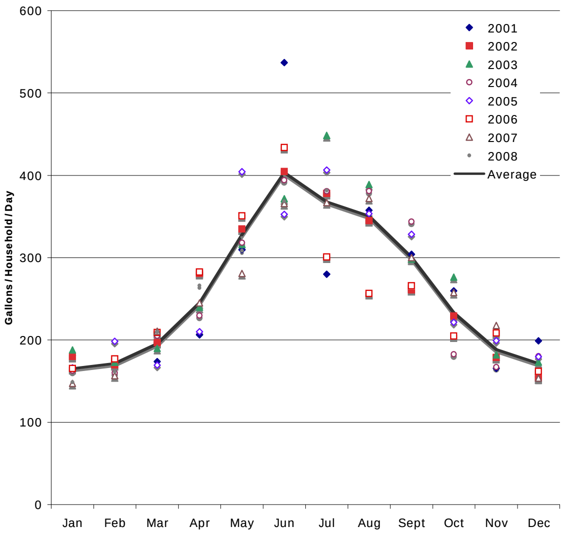

Figure 1. Water use in the LMWC

Since there is considerable variability in water use from year to year, a statistical measure of that variability was calculated. A common measure of variability, and the one used here, is the “standard deviation,” which is described in virtually all elementary statistical texts. It allows one to make statements about the probability of certain events, assuming what is called a “normal” distribution of data. We want to plan conservatively for our system, and to do so, we plan to meet water requirements that are higher than the average. The standard deviation allows us to estimate a water use that would be exceeded only once in ten years, for example.

There is a point that needs to be made regarding this statistical approach. It is possible to calculate for each month the water use that would be exceeded only once in ten years. But a whole year of such months would be extremely rare because each one has only a 10% chance of occurring and a string of 12 such events is way out of the ordinary. Think of flipping 12 consecutive heads – and there the probability for each event is 50%.

The water use data include all water pumped from the wells, not just the water that is sold to our customers. Like most water systems, we experience a difference between what is pumped from the wells and the aggregate of water sold to our members and other water uses like flushing the lines, watering the properties we own and so forth. This “unaccounted for” water is included in the water use estimates.

To obtain the estimate of total water use we can simply multiply the water use per household per day times the number of households and the number of days in a month. We are primarily concerned with meeting summertime water requirements, so we can consider meeting the June, July and August demand. We actually have two concerns: 1) we need to be able to meet the “peak” water demand and 2) we would like to know how much water from Well #3 must be processed so that we can estimate the treatment costs. For the first concern, we consider average demand in June, the once in ten tears (or “1 in 10”) demand, and the peak demand we have experienced to date. For the second, we consider the average demand for June, July and August and the highest combined demand for those months that we have experienced since 2001. The requirements are as given in Table 1.

Table 1
Water Use Requirements

Condition	**Usage gal/day/household**
“Average” peak water use in a month	403.5
“1 in 10” peak water use in a month	480.0
Highest use experienced, June 2001	536.9
Average use: June, July & August	403.5, 367.8, 350.6
Highest use: June, July & August 2003	371.6, 448.4, 388.9

We will require that our system be able to meet the “1 in 10” peak water use. We will base costs for the treatment system on a combination of average use for June, July and August and highest three-month use experienced. Note that the highest three-month use experience is only about 8% larger than the average, so the cost difference is not huge.

2. Planning for a New Well

2.1 What Are Our Current Assets?

The LMWC has, in effect, four wells, one of which produces water that is not compliant with current Arsenic concentration limits. We believe that we can use that water, either by treating it to reduce the Arsenic content, or by diluting it. In the past, in this type of planning, we have assumed that our wells would have more or less constant capability to deliver water – in other words, if a well can deliver 50 gpm now, it should come close to that several years from now. After several years of experience with our wells, we believe that we should consider a gradual decrease in the capability of the wells when plan for the future. The reduction in capability occurs, in part, because the water table is lowered and the water must be pumped through a greater vertical distance to reach the surface. However, we now believe that pumping also causes changes in the material surrounding the well, compacting it and thereby increasing the resistance to flow in that material and reducing the well’s capability to deliver water. Also, the holes in the screen portion of the well casing tend to get smaller over time due to a “hard water” buildup. In this analysis, we assume that well capability decreases by 2% every year. At this rate, by the 11th year, well capability would be down to 81.7% of its starting value. We assume that, at that time (between the 10th and 11th year of operation), the well would be cleaned, which would increase its capability by 15%, restoring it to 94% of the starting value. Table 2, on the next page, shows the estimated capabilities of the four wells.

For Well #1, we have assumed that the current refurbishment will result in a well that can produce 30 gpm at the start and would have an expected lifetime of 15 years. For well #2, we have taken the current capability as 21 gpm and its remaining life as 13 years, including 2008. At Well #3, the electricity available at the site limits the capability. We believe that it is capable of delivering 65 gpm for 17 years, starting in 2009. If the water from Well #3 were treated, there would be an additional pressure drop across the filter media that we estimate would reduce its capability to 50 gpm. For Well #5, we have assumed a 2008 capability of 105 gpm and a well cleaning in 2017-2018. We have estimated its life as 30 years. A shorter life, say 25 years, would not influence the results of this study.

At Well #1, we assume an Arsenic content of 3 ppb. We assume 9 ppb at Well #2, and 5 ppb at Well #5. For Well #3, we assume 27 ppb if the water is untreated and 10 ppb if it is.

Table 2
Assumptions Regarding Existing Wells

	Well#1	Well #2	Well #3 Untreated	Well #3 Treated	Well #5
Arsenic, ppb	3	9	27	10	5
2008	0.0	21.0	0.0	0.0	105.0
2009	30.0	20.6	65.0	50.0	102.9
2010	29.4	20.2	63.7	49.0	100.8
2011	28.8	19.8	62.4	48.0	98.8
2012	28.2	19.4	61.2	47.1	96.8
2013	27.7	19.0	60.0	46.1	94.9
2014	27.1	18.6	58.8	45.2	93.0
2015	26.6	18.2	57.6	44.3	91.2
2016	26.0	17.9	56.4	43.4	89.3
2017	25.5	17.5	55.3	42.5	87.5
2018	25.0	17.2	54.2	41.7	98.7
2019	24.5	16.8	53.1	40.9	96.7
2020	24.0	16.5	52.0	40.0	94.8
2021	23.5		51.0	39.2	92.9
2022	23.1		50.0	38.5	91.0
2023	22.6		49.0	37.7	98.2
2024			48.0	36.9	87.4
2025			47.0	36.2	85.7
2026					83.9
2027					82.3
2028					80.6
2029					79.0
2030					77.4

Finally, we have two storage tanks; one has a capacity of 100,000 gallons and the other a capacity of 200,000 gallons. They operate as a single 300,000 gal. tank. We consider them full when the water level is at 12.5 feet.

2.2 So, When Is a New Well Needed?

In planning for future operation, we normally assume that wells (or their pumps, actually) operate not more than about 60% of this time. This has a number of benefits:

- A loss of 40% of the system capability can be experienced without a severe restriction on flow. For example, using the information in the table, the total capability would be close to 200 gpm, so a loss of about 80 gpm (Wells #1 & #3) could be tolerated.
- It is the basis by which the State Engineer determines that a development has enough water for a certain number of years (40 years in our case, but the current standard around here is 100 years)
- Also, we believe that running the pumps no more than 60% of the time yields operating benefits such as reduced maintenance, higher reliability, and so forth.
- One theory of well operation is that, as the well pulls in water from its surroundings, it also pulls in “fines” which has the effect of compacting the material through which the water travels. This

is believed to be driven by the water velocity, so if we do not "pump hard," we may reduce the effect.

If we consider full build-out to mean 370 homes, we will need to pump almost 104 gpm (24/7) to meet average summertime needs. However, we will probably not have 370 households for a number of years – we only have 319 at this time. To try to simulate future growth in the two developments, we have assumed 325 houses in 2009 and an increase of 5 houses each year until we reach 350 in 2014. After that, we assume just two new houses per year. We want our system to be able to meet summertime demand and still have the pumps operate not more than 60% of the time. Figure 2 shows the pump use in future years for three conditions: 1) average use in June; 2) June use that is exceeded only once in ten years; and 3) use in June 2001. The dashed lines assume the existing configuration; the solid lines are for a 100 gpm well coming on-line in 2016.

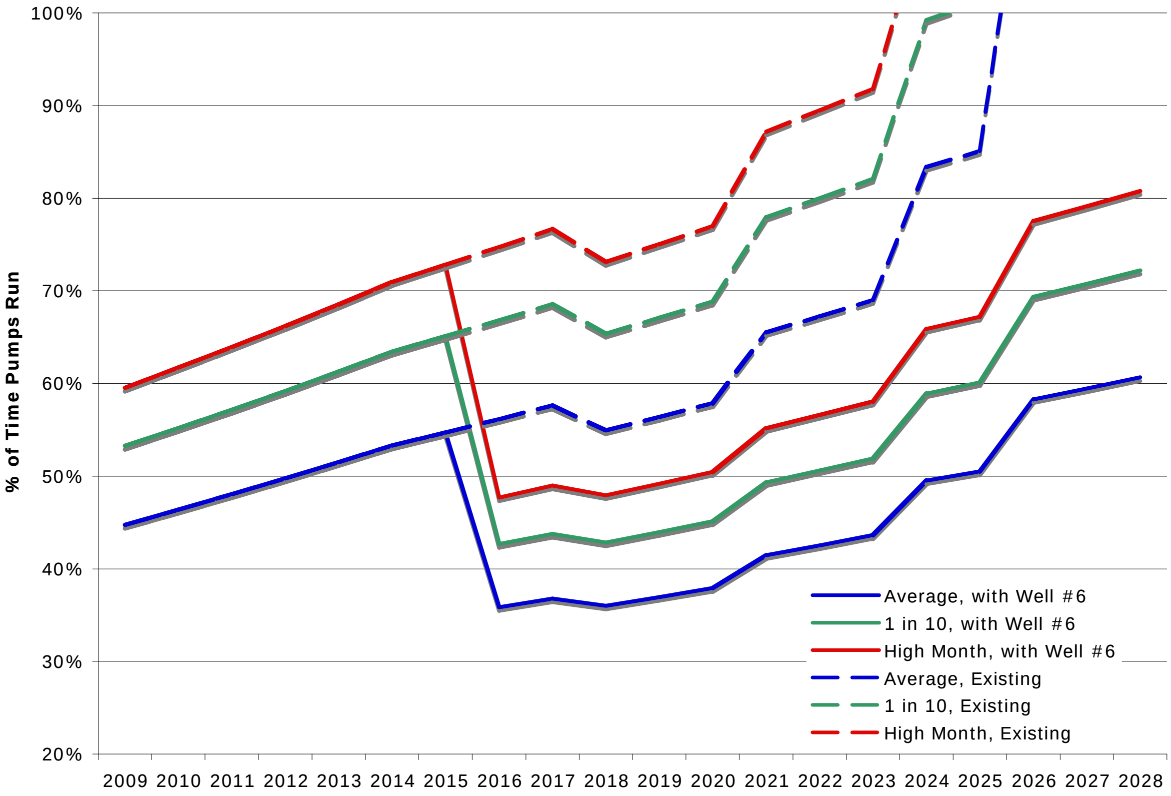

Figure 2. Expected Future Pump Operation

For an average year, pump operation does not exceed 60% until 2021. However, if we have a high water use year, we could reach 60% as early as 2013. A reasonable compromise is to have a new well in 2016. This would limit pumping times to about 67% in the year before the new well came on-line, similar to our current pump use. If there were problems with the new well, a two-year delay would not be terrible, partly because an expected cleaning of Well #5 before the high use period in 2008 would provide a small boost in capacity. An "earlier, rather than later" approach also provides some protection against loss of one of the smaller wells. Selection of a "target year" for bringing Well #6 on-line will depend on a balancing of risk versus cost, but 2016 seems to be a reasonable time.

Figure 3, on the next page, shows what our installed capacity would be if Well #6 were to be brought on-line in 2016. By comparison, the capacity needed to handle average summertime use at

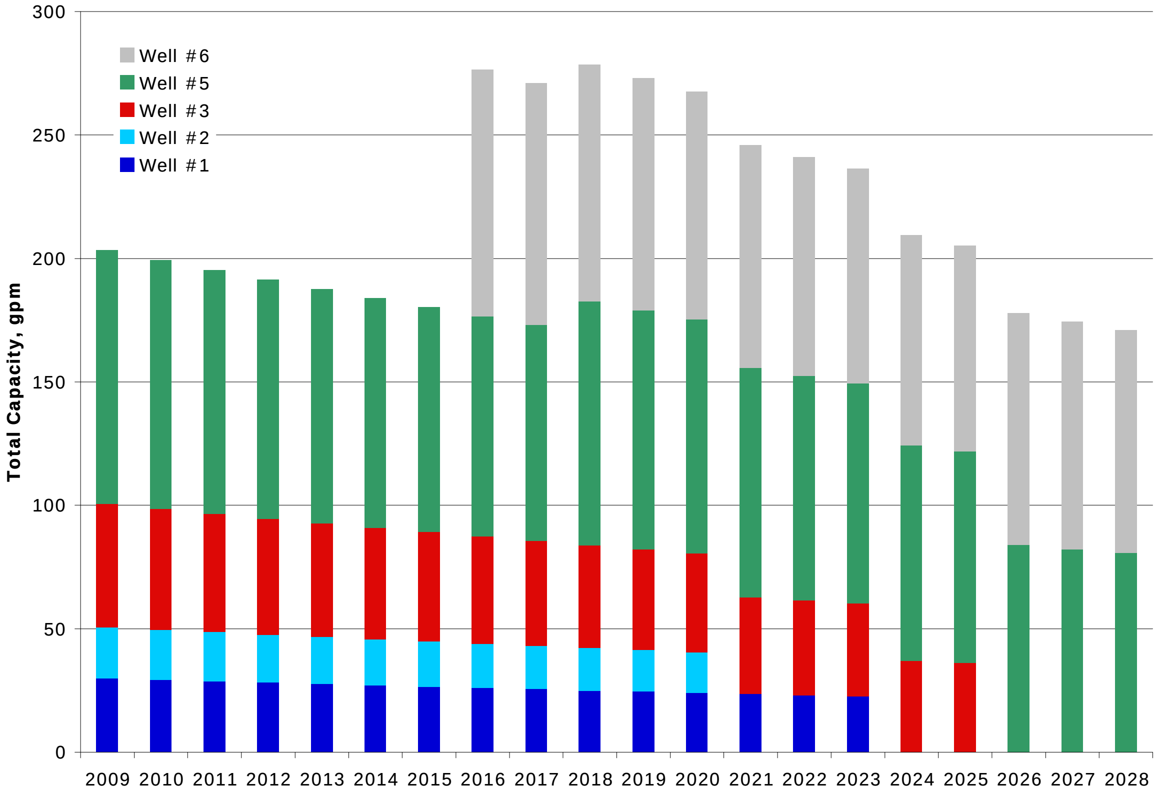

Figure 3. Aggregate LMWC Capacity with Well #6 in 2016

full build-out is about 175 gpm. Note that another well will likely be needed around 2027. This leads to the conclusion that a new well will be required about every 10 years.

3. How can we Make Use of Water from Well #3?

3.1 Treatment of Well #3 Water

The "baseline" approach we are using for Well #3 is to assume we treat that water to reduce its Arsenic content to 10 ppb or less. The questions we need to ask are, "For how long must we treat the water?" and "How much water must we treat?" If we have average flow in 2009, we can meet demand without using any water from Well #3. On the other hand, if we had a year like 2001, we would need to treat the water. So part of the answer to the first question depends on the risk we are willing to take with respect to how much the pumps are required to operate. The rest of the answer is easy – once Well #6 is on-line, we will be able to meet demand without Well #3, so then we can turn it off again.

Figure 4, on the next page, shows pump operation between 2009 and 2015, the last year before the assumed operation of Well #6. The chart covers four water use scenarios: 1) average water use, in which June is the high month and the average use is 403.5 gallons per day per household; 2) the highest three-month use experienced (2003), in which case July is the high month and the use is 448.4 gallons per day per household; 3) usage expected to be exceeded only one year in ten, where the high month is June and use is 480.3 gallons per day per household; and 4) the highest month experienced (June 2001) with use of 536.9 gallons per day per household. This figure allows us to evaluate the risk associated with various courses of action. Perhaps the easiest way to illustrate this is to do an example.

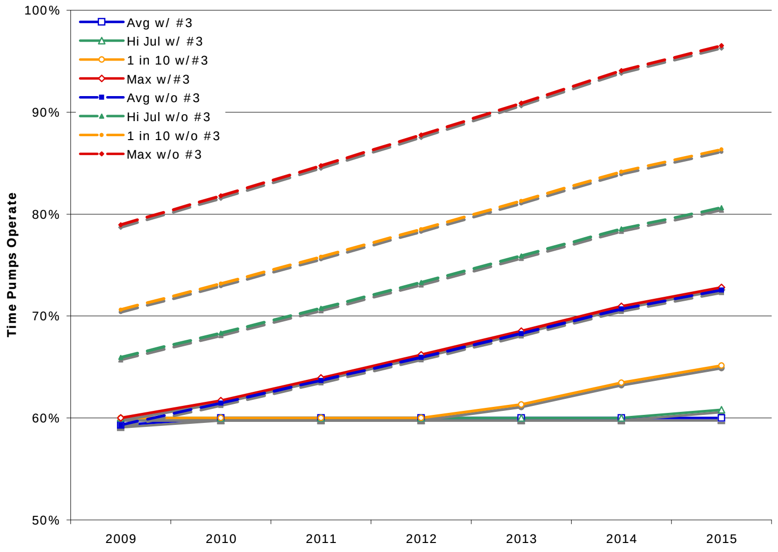

Figure 4. Pump Utilization between 2009 and 2015.

Let us suppose that we provide a treatment facility beginning in 2012. If we have average use during the period 2009 to 2011, the pumps will run up to 63.7% of the time. We are actually running the pumps more in 2008, so this does not seem too bad. If we experienced a three-month period like we had in 2003, the pumps would need to run almost 71% of the time – more than we needed this year. And if we had a “one in ten” year, the pumps would have to run up to 75.8% of the time. If June, 2001 re-occurred, they would run about 85% of the time – clearly more than we would like. One way of deciding how high we want to go is to look at pump operation in the worst case if we have Well #3 online. That is the solid red line on the chart, and it shows that, even if we had Well #3 running, we would have to run the pumps almost 73% of the time to meet that level of water demand. Without Well #3, we would exceed that in 2011 for the “one year in ten” scenario. That might be a reason to have the treatment plant operating in 2011, rather than 2012.

Table 2
Water Treatment Requirements

Year	Average	High 3
2009	0	91,500
2010	22,600	128,000
2011	56,300	186,000
2012	93,400	267,900
2013	159,500	372,400
2014	251,700	478,600
2015	324,600	542,100

The amount of water that would have to be treated is given in Table 2. Under “Average” conditions, no water is required to be treated in 2009, but 91,500 gal would have to be treated during the highest three months we have experienced. As the capacity of the wells decreases and the number of households increases, the water treatment requirements increase also. Note that these requirements refer to the three-month period from June through August. It is unlikely that the requirements would exceed the values in the table because a higher water use in one month implies a lower use in another – at least according to our historical water usage pattern. This information can be used to estimate annual operating costs for the treatment unit.

3.2 Use of Well #3 Water Without Treatment

There are at least three schemes we could use to incorporate Well #3 water without treatment. Before getting into them, however, we need to discuss the current control system for our pumps. We operate the three pumps simultaneously and they are turned on and off depending on the water level in the tank(s). When the water level drops below a certain point, the pumps come on and begin to fill the tanks. Eventually the water fills the tanks and, at that level, the pumps are shut down. Then the tank drains as people use water until the lower limit is reached and the pumps are turned on. The key features are that 1) the pumps are either on or off – if we want to limit the flow from a particular well, we must throttle the pump manually; our control system does not now have that capability; and 2) water level in the tank is currently used to start and stop the pumps – we can use more than one water level; we could start one pump at the current water level and if the water level continued to fall and it passed another limit, we could start another pump.

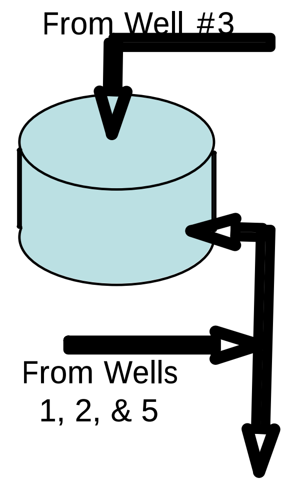

Figure 5. Water Flow when Untreated Well #3 Water is Used

Option 1: Variable Flow Control System - All the schemes for using water from Well #3 without treatment involve building a temporary pipeline from Well #3 up to the tanks and pumping the water directly from Well #3 into the tanks. In this way, the arsenic in the Well #3 water could be diluted to less than 10 ppb. However, this is not as simple as it sounds. Part of the problem is that the water from the other wells goes into the piping system and not into the tanks. That means that the water going into the tanks from the compliant wells is less than their capacity by the amount of water that is being used. Figure 5 illustrates this. When the pumps are not working, the tanks drain to provide the water supply. When the pumps do pump, the water goes first to supply the current demand and second to filling the tanks. For this control scheme to work, we would need to limit the flow of water from Well #3 to about 25% of the flow into the tank. We do measure the flow of water into and out of the tanks, but we do not currently have a means to automatically vary the flow from Well #3 in response to a control signal of some sort. Also, we would need to measure the Arsenic concentration in the tanks and add that to the control scheme to make sure Well #3 is not pumping if the concentration approaches 10 ppb. This approach clearly requires a somewhat more sophisticated control system.

Option 2: Tank Level Control System – We could avoid adding the more complex control system by devising one in which we use the water level in the tanks to start the pumps, much as we do now. This would involve first starting the compliant wells to begin filling the tanks, then starting Well#3 to finish filling them. The control sequence would work like this: 1) the water level in the tanks would drop to the point where the wells come on, but Well #3 would not be started at that time - only the compliant wells would come on; 2) when the water level reaches a second "set point" Well #3 would come on and all pumps together would finish filling the tank; 3) when the tank becomes full, all pumps shut off. Figure 6 shows how the arsenic content in the tanks would change with time. The left hand side of the figure shows the arsenic content decreasing as the tank fills with compliant water. The right-hand side shows the arsenic content increasing as Well #3 water is added to "top off" the tank. Two situations are shown. The blue line is for an average June and the pumping capacities we expect in 2009. The red line is for the maximum July and pumping capacities decreased to 2015 levels. Note that there is not a big difference in the water level at which Well #3 starts pumping. But be aware that the entire fill cycle takes about half a day in for the blue curve and a whole week for the red one. The implications are that it may be easy to set the control system so the Well #3 pumps come on at the right time because the set point does not depend strongly on the situation. On the other hand, that also means that we probably cannot set it

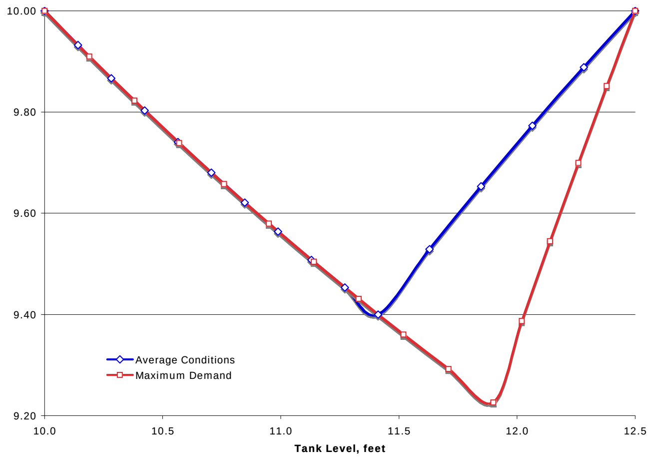

Figure 6. Arsenic Concentration as a function of Tank Level for "Case 2" use of Well #3 Water

accurately enough to accomplish the desired dilution – we would likely need to put an arsenic indicating device into the tank outflow and shut off Well #3 when the concentration exceeded the limit or there was no inflow to the tanks. The implications of the long cycle time are that the pumps are running most of the time. In general, the Well #3 pump runs only about 3 hours to make its contribution to filling he tank It only takes about half a day to drop the tank level far enough to start the pumps. That means that the pumps are running over 90% of the time. The main problem with this approach (and that in "Case 1") is that in times of high demand, there is very little compliant water to mix with Well #3 water and so Well #3 contributes very little to our pumping capability

Option 3: Mix with another Well - A way to better use Well#3 would be to "guarantee" a larger supply of compliant water with which to mix the high arsenic water. This could be done by bringing water from another compliant well directly to the tanks to mix. The logical choice would be water from Well #5. Although Well #2 is closer, its arsenic concentration is fairly close to the 10 ppb limit and would not dilute very much water from Well #3.

Comparison of Alternatives – One way to look at the various alternatives is to look at how much of the capacity of Well #3 can be used. Ideally, we would like to use as much water from Well #3 as possible to minimize the water we require from the other wells Figure 7 shows what capacity is required from Well #3 for the various alternatives we are considering. For treated water, we minimize the amount of water used to minimize the cost. Thus, the growth in required capacity for the situations where the water is treated represents the growth in population of our service area. For the "1 in 10" case, the later decline is our prediction of the decline in capacity as the well ages. For Option 3, the Well #3 capacity that we can use is about 30% of the Well #5 capacity, and as Well #5's capacity declines, so does the amount of water we can use from Well #3. The curves for Options 1 & 2 illustrate a sort of "counterintuitive" behavior – the greater the demand, the less Well #3 water we can use. That is because under greater demand conditions, more compliant water goes directly to the users and less is available to fill the tanks and to serve as a diluent for water from Well #3. In general, the capacity to pump compliant water is between 135 and 155 gpm. Using treated water provides the greatest increment to that – up to about 45 gpm. The options involving untreated water provide less capability, but at a possibly lesser cost.

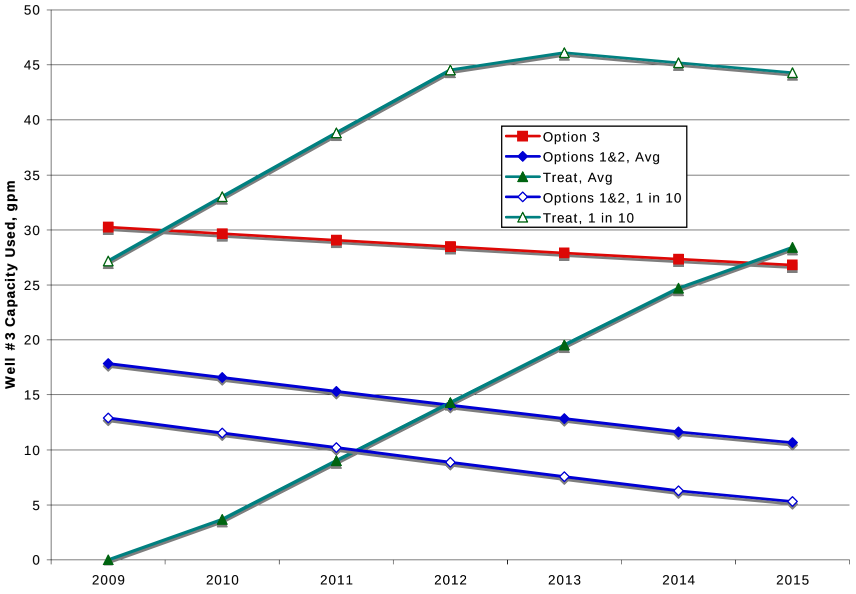

Figure 7. Well #3 capacity used.

Another way to look at the alternatives is to compare pump utilization. Our goal is to run the pumps no more than 60% of the time. Figure 8, on the next page, shows the pump utilization for the various alternatives. If the water is treated, the compliant pumps will be run about 60% of the time. This is because that is the way the operating scheme was devised – to have the compliant pumps running about 60% of the time and to make up any additional requirements from Well#3.

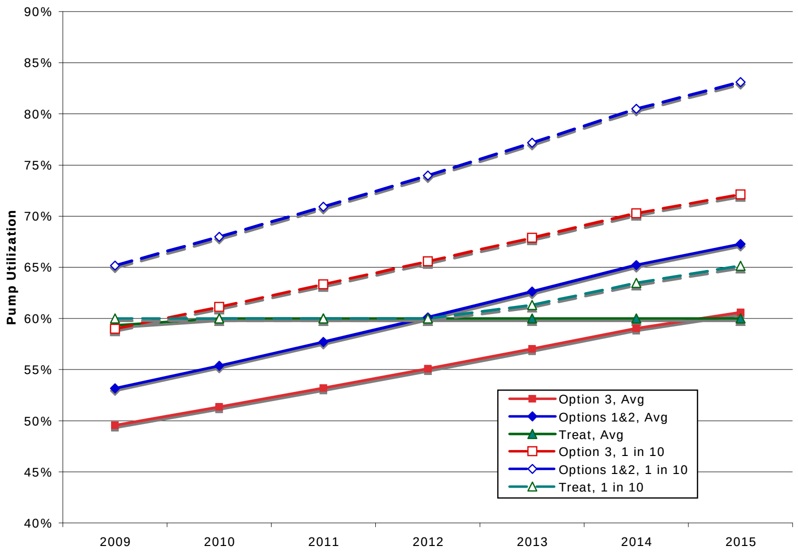

Figure 8. Utilization of Compliant Pumps

Note that for the “1 in 10” case, the fact that Well#3 capacity is fully utilized causes the pumps to run more than 60% of the time. For “average” years, any of the three options for using untreated water would be satisfactory. Options 1 & 2 would yield a pump utilization of greater than 60%, but it would not exceed 70% and could, perhaps, be managed. However, for high demand situations, Options 1 & 2 are clearly unsuitable. Option 3 is somewhat marginal – the pump utilization exceeds 60% in almost every year and exceeds 70% for the last two years before Well #6 comes on line. Still, if Option 3 allows a significant cost savings, it might be a worthwhile risk. The decision depends on balancing cost and risk.

Conclusions

This report provides information that can be used to develop a plan for capacity additions to the LMWC water system. The first issue addressed was when Well #6 should be brought on-line. Figure 2 provides some useful information to help in that determination. In effect, any time between about 2013 and 2020 would be satisfactory. The earlier times place more stress on financing the well and the later times are riskier in terms equipment use. Current planning assumes Well #6 is online around 2016.

The second issue was how to use noncompliant (with Arsenic limits) water from Well #3 in the meantime to avoid over-taxing our existing equipment. The current plan is to install a portable/temporary treatment facility to bridge the gap until Well #6 is online. However, this is an expensive solution, not only in terms of the capital cost, but also the operating costs. It may be possible to avoid some of the operating costs by relying only on the compliant wells for the next few years, and using water from Well #3 only to supplement the water from the compliant wells. Figure 4 and Table 2 provide the technical information needed to develop an operating strategy that minimizes operating costs.

A different approach would be not to treat the water from Well #3, but to discharge it directly into the storage tanks to dilute the arsenic content. One approach, to combine it with water from Well #5, could meet our needs for the next few years. Other approaches investigated seem not to provide the needed capacity. Figure 8 provides information for that assessment.

Selection of a final plan will depend on the costs of the various alternatives and the risk deemed appropriate for the Cooperative.

Appendix A

Water Use Data

Every month, when household meters are read, the meters on the wells are also read. This information is reported by the Bookkeeper and is given as the gallons pumped and when divided by the number of days since the last reading and by the number of households (or meters) as the gallons per day per household. This generally produces a figure that is different than what would obtain by adding up all the individual household meter readings and performing the same arithmetic operations. The difference, once known uses such as line flushing and landscape watering are deducted is known as "Water Unaccounted For" and it is generally 5-10% of the water pumped. This is common for water systems. The point to be made here is that, since the measurements are made at the wells and not at the households, the water use data includes everything, ever water unaccounted for. The data collected since January 2001 are given in Table A-1. These are the data plotted in Figure 1.

Table A-1
Monthly LMWC Water Use in Gallons per Day per Household.

	2001	2002	2003	2004	2005	2006	2007	2008	Average	Std.Dev
Jan	163.68	179.96	187.94	162.79	166.21	165.29	147.25	148.70	165.23	13.83
Feb	175.40	169.94	173.06	159.97	198.40	177.03	156.62	161.41	171.48	13.26
Mar	173.91	196.80	189.83	204.95	169.44	209.03	210.51	209.75	195.53	16.39
Apr	206.38	280.73	239.76	229.46	210.03	282.48	245.16	266.23	245.03	29.56
May	309.52	334.87	316.09	318.12	404.36	350.88	280.77	308.33	327.87	37.03
Jun	536.90	404.58	371.59	394.00	352.71	433.67	365.77	368.41	403.46	59.82
Jul	279.78	377.85	448.41	380.75	406.41	300.98	366.90	381.55	367.83	54.33
Aug	357.58	345.04	388.91	380.93	353.42	256.59	371.80		350.61	44.28
Sept	304.17	261.22	298.30	343.88	328.42	265.86	299.89		300.25	30.06
Oct	259.74	228.90	276.36	182.58	221.38	204.78	257.73		233.07	33.41
Nov	165.52	178.68	181.96	167.20	199.08	208.65	217.68		188.40	20.37
Dec	198.90	153.85	173.13	180.16	179.56	161.83	153.76		171.60	16.40
Total	95,249	94,669	98,713	94,438	97,012	91,769	93,497		94,910	2273

The average wintertime (December, January and February) use is about 169 gal/d/household and the average summertime (June, July and August) use is about 374 gal/d/household, or roughly a factor of 2.2 higher in the summer than in the winter. The standard deviations in the summer months run 12-15% of the averages. In the winter they are less than 10%. This would seem to indicate that the variability has a major component related to landscape watering and the variability of rain during those months. The standard deviation for the full year is only about 2% of the average. From a planning perspective, this means that we can make fairly accurate projections of annual water use and, therefore, our requirement for water rights. On the other hand, planning for summertime needs involves greater consideration of variation in water demand and provision of measures to accommodate higher than normal water demand.

Planning for the summertime generally involves considering "extreme" events – that is, asking, "How bad could it get?" Table A-2 shows the extreme events that we have experienced over the last eight years. We consider a high water use month to determine the needed capacity for the system. We are considering treating the water from Well #3, and to estimate the costs for that we need to know how much water would be treated. Water use over the three summertime months is expected to give us a good estimate of that cost. These extremes are highlighted in Table A-2.

Table A-2
High Water Use Events

	2001	2002	2003	2004	2005	2006	2007	2008	Average
Hi Month	**536.90**	404.58	448.41	394.00	406.41	433.67	371.80	381.55	403.46
M J & J	1126.21	1117.31	1136.09	1092.87	1163.48	1085.54	1013.44	1058.29	1099.15
J J & A	1174.26	1127.47	**1208.91**	1155.69	1112.54	991.24	1104.47	749.96	1121.90
J A & S	941.53	984.11	1135.63	1105.57	1088.25	823.43	1038.60	381.55	1018.69

Note that, in planning for the future, it is not necessary that we be able to meet every eventuality. For example, we operate our system in such a manner that we have some ability to respond to unforeseen circumstances. It is not necessary that we be able to accommodate a 537 gal/d/household month and still retain all of the margin. We can design the system to meet a less extreme situation and then use the margin for the rest. The question is, “What should be the design basis?” In the past we have used the concept that we should be able to accommodate situations that do not occur more often than once in ten years.

Figure A-1 shows the demands that are placed on the system during the summer. The black line is the average summertime use. The green line is the highest three-month use drawn from our own experience – it represents 2003. The black “asterisks” are the summertime monthly usages that we expect to be exceeded only once in ten years. The rest of the points are actual use since 2001.

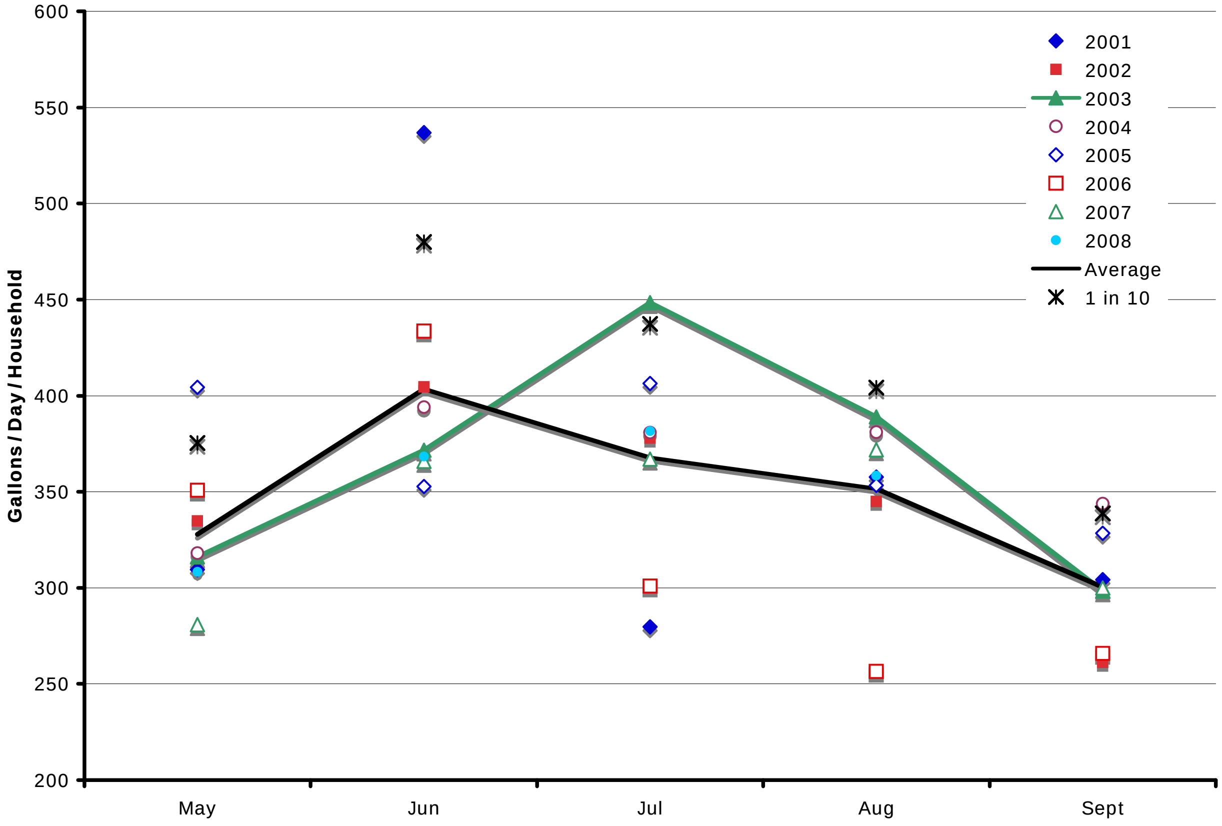

Figure A-1. Summertime LMWC Water Use