City of Kingsburg

2023 Water System Model Update

February 2023

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Executive Summary

The City of Kingsburg last updated the Water Master Plan in 2003. In 2007, a computerized water model was developed by digitizing the city's existing computer information system and concluded the following:

- Well 16 is needed to meet fire flows / max hourly demand conditions. This improvement has been completed.
- Local fire flow deficiencies were identified but can be remediated with strategic pipeline upgrades.
- A ground level storage tank is not needed to provide fire flow demands. Fire flows are easily satisfied by constructing another well at a much lower cost. Analyses also showed that water storage and emergency system surge relief can be accomplished by more practical and economical means.

Other recommendations included:

- All wells should be retrofitted with permanent stand by generators with auto-start features. These improvements have been completed.
- The existing, elevated water storage tank should be abandoned as a water storage appurtenance and preserved as a landmark/monument. This improvement has been completed.
- Emergency surge relief facilities should be installed near the tank inlet/outlet and throughout the city to ensure excessive water pressures do not damage water mains. This improvement has been completed.
- Continue building a 12" diameter backbone grid on 1-mile streets with interlocking 8"diameter 1/2-mile looped network
- A water conservation program should be implemented. Kingsburg residents use approximately 500 gallons / person / day compared with the statewide average of 250 gallons / person / day. A conservation program could delay the need to construct new well facilities in the future. This program has been implemented and per capital usage has significantly reduced.

2022 Water Model Findings

Based upon information gathered from the SCADA system, field analyses, water production data and discussions with City staff, a water model was developed using the computer program H2OMAP. The model was carefully calibrated to actual field conditions and the following scenarios were analyzed:

- Existing Conditions (Average and Maximum Day Simulations)
- Future System (Full Build-Out to City General Plan Limits)

The water model concluded the following:

- The current water system (following the construction of Well #16) is operating optimally.
- The City currently has 1,823 acres of developed land and will impact another 1,411 acres in building out the City to its General Plan limits.
- There are still a large amount of 2” and 4” pipes that require replacement.
- The City will require at least 3 (possibly more) new wells in the build out of the City general plan.
- A well ratio of 3.85 gpm shall be applied to each future acre (gross) of new land developed.

Chapter 1
Background and Purpose

1.1 Background and Purpose

The City of Kingsburg (City) is located in southern Fresno County, approximately 20 miles south of Fresno, California. The City was incorporated in 1908 and had a 2000 census population of 9,199 and a July, 2005 population of 11,184 (+22.2%). As of the most recent government census, Kingsburg recorded a 2020 population of approximately 12,219 and is currently growing at a rate of 0.30% annually.

The City of Kingsburg Municipal Water System contains the following:

- 79 miles of pipe (ranging from 2” to 12” in diameter)
- 7 wells (4 static + 3 variable frequency)
- 6 pressure relief valves (emergency pressure relief only)

The purpose of this hydraulic model update is to determine the current operational parameters of the existing hydraulic network and to ascertain the various impacts of proposed water facility infrastructure, specifically new wells and larger water transmission mains as may be required for the full build out of the City of Kingsburg General Plan.

1.2 Historical Reference

As this report represents an ongoing update of past water master plans, it is informational to review past recommendations and conclusions established in previous Water Master Plans reports.

Recommendations of the 1982 Water Master Plan

1. Existing wells Nos. 4, 5, and 6 should be abandoned because of the persistent presence of DBCP in the water at concentration above the DHS action level of 1 PPB.
    a. *Wells 4, 5, and 6 were abandoned due to DBCP contamination.*
2. Treatment of the water supply for removal of DBCP is expensive and should only be considered if a new, deeper well fails to eliminate the DBCP contamination.
    a. *It appears that new wells have adequately addressed past DBCP contamination problems. All new wells are below DBCP contamination plumes.*
3. The ISO recommended fire flow cannot be achieved in the higher risk areas of the City because of inadequate supply capacity and the presence of small-diameter piping in the distribution system.

a. *The City has undertaken measures to install larger diameter pipelines throughout the distribution network. This has subsequently increased flow capacities that will ensure adequate public safety during times of required fire flow. A few 2" and 4" pipelines remain and must be replaced as quickly as possible.*

4. Approximately 38% of the City's 188 existing fire hydrants are substandard units with restrictively small barrels and single outlets.

    a. *Several parts of town are still served by 4" diameter pipelines. Such a small diameter pipe causes reduced flow rates for fire extinguishing purposes.*

5. The existing elevated storage tank is much too small to provide effective assistance during periods of high demand. The most cost effective means of meeting high demands in Kingsburg is to drill additional wells, rather that to increase storage capacity.

    a. *Since the 1982 Master Plan, the City has drilled 4 new wells. Kingsburg is in a unique situation in that it retains a very good aquifer with a subsequently high water table. Because of these benefits, it is more economical to simply pump water from the ground when it is needed.*

6. Four new production wells will be required in Kingsburg to meet the present demand for water after existing wells Nos. 4, 5 and 6 are abandoned. A fifth well will be necessary before 1992 if the City continues to grow at its historic rate.

    a. *The City constructed wells 9, 10, and 12 in order to abandon wells 4,5, and 6. Well 13 was constructed shortly thereafter while wells 14 & 15 have since been constructed.*

7. Because of the high cost of auxiliary power and the general reliability of the PG&E system, auxiliary power should not be provided for the four proposed wells.

    a. *Auxiliary power was not provided to any of the new wells.*

8. At an average of 408 gpcd, the gross water usage in Kingsburg is among the highest in the Central Valley. Approximately 80% of all water delivered by the municipal system is used by residential customers.

    a. *City of Kingsburg has significantly reduced the per person rate of consumption.*

9. The probability of eliminating the DBCP problem by constructing deeper wells which draw water exclusively from strata below 400 feet appears quite high. Test-well procedures should be utilized before drilling the production wells.

    a. *After years of well production, this strategy was implemented and has been instrumental in ensuring that the City of Kingsburg continued to deliver safe and reliable water supplies.*

10. Proceed with the engineering and construction of proposed Well No. 9 at 24th Street and Erling Way. Precede construction of the production well with a test-well analysis.

a. *Well No.9 was constructed and is currently in operation.*

11. Secure sites for the other three proposed production wells.

    b. *Sites were secured for Wells 10, 12 and 13.*

12. After Well No.9 has been in service for a period of time and proves satisfactory, proceed with the test well drilling at the other three locations. Complete the engineering and construction of the remaining three production wells.

    c. *Wells 10, 12 and 13 were constructed.*

13. Upon the successful completion and start up of Wells 9 through 12, abandon existing Wells 4, 5 and 6.

    d. *After construction of Wells 10, 12, and 13 - Wells 4, 5, and 6 were abandoned.*

14. Inspect and repair Wells 7 and 8 to restore capacity. Install flow meters on each well and record readings.

    e. *Wells 7 and 8 were eventually abandoned.*

15. Begin to implement the high priority improvements on a schedule which, in the judgment of the City Manager, Director of Public Works, and City Council, fits the financial resources and political realities of Kingsburg.

    f. *All Urgent priority improvements have since been constructed.*

Recommendations of the 2003 Water Master Plan

Citing the 2003 Water Master Plan conducted by Yamabe and Horn, the following recommendations and the subsequent action were taken.

1. Replace all remaining 2" and 4" pipes

    a. *The City is still on a schedule to replace the remaining 2" and 4" pipe. Note: A 4" pipe cannot deliver requisite fire flows due to insurmountable friction losses in the pipe.*

2. Construct a new well with a Variable Frequency Drive (VFD) motor.

    a. *The study found that during a Max-Day plus fireflow event, there was insufficient flows available in the system. However, even with a new well, should a fire occur when the largest producing well was out of service, the city would be operating in an 'at-risk' condition. Therefore, well #14 was equipped with a VFD motor.*

3. Remove the existing elevated tank and take it out of service.

    a. *The elevated water storage tank has been removed from service.*

4. Construct two (2) 600,000 gallon storage tanks.

    - Reasons for tank construction:

- Pump during off-peak hours to save on electricity costs.
- Two tanks needed to distribute costs over time and to use one tank when the other is being serviced.
- The ground tank will allow the City to spread the cost of the tank over more years and still be less expensive.

a. *These improvements have not been made.*

5. Construct a 12" main grid on ½ mile intervals and an 8" grid on ¼ mile intervals. All larger commercial, multi-family, and industrial land uses should be served by an 8 inch pipe.

   a. *Sound water distribution practices ensure reliable sources of delivery and redundancy. By constructing a grid network, the City is providing multiple routes of delivery in time of maintenance, repair and/or disaster.*

Recommendations of the 2006 Water Master Plan Update

A hydraulic water model update was conducted by Ennis Consulting in 2006. The water model update report provided the following recommendations and subsequent action.

1. Construct new wells in lieu of a storage reservoir (at-grade or elevated)

   a. Given the quality and quantity variables of the groundwater aquifer, the City of Kingsburg should choose new supply sources over storage. As the water table is high, constructing new wells, capable of exceeding 1000 gpm, should take precedence over storage alternatives. Reservoirs are generally reserved for communities where:

      i. The ability to provide adequate fire flows from wells (<500 gpm) is diminished due to low water table and/or groundwater transmissivity issues.

      ii. The ability to provide very large fire flows to industrial and commercial uses is diminished due to undersized system production and system distribution. Tanks are generally constructed adjacent to such large fire needs.

      iii. Costs are abnormally high due to pumping deep groundwater or where treatment systems are required for contaminant removal.

      iv. Surface water supplies must be treated at a constant rate and stored for system delivery and/or fire and/or emergency storage requirements.

      v. Unreliable power supplies result in periods of brown-outs or black-outs, rendering a system incapable of delivering system demands.

      vi. Local topographical conditions allow for energy savings (i.e. constructing a tank on a hill next to the treatment plant).

Since the City of Kingsburg, at the present time, does not have any of the issues generally reserved for water storage, the City should construct new wells over new storage. However, this does not necessarily mean that the City should never construct a storage system. As the system expands and as needs change, the situation may present itself where the decision to construct a reservoir may again be considered.

b. The City elected to construct Well #16 and place it in service.

2. Remove water storage capacity of the elevated tank.

   a. The absence of lateral bracing on the 60,000 gal. water tank requires that the tank no longer be used for water storage. The added advantage of the water tank is that it now serves as a buffer in case of pressure surcharge in the system. However, given the recent installation of the SCADA system and subsequent pressure switches installed at each of the wells in the system, the likelihood of over-pressurizing is unlikely. The volume (60,000 gal.) is miniscule and will not be missed.

   b. The City abandoned the elevated water storage tank in 2010 and it was structurally stabilized and serves as a historical monument.

3. Place a Variable Frequency Drive (VFD) on Well 16.

   a. Given the proximity of the new Well 16 to Well 9, Well 16 should be equipped with a VFD motor. A VFD would allow local pressures in northeast Kingsburg to be remain constant, regardless of system demands. In addition, the motor for Well 16 should be designed to produce no less than 1,500 gpm at 55 psi.

   b. A VFD was installed with the construction of Well #16.

4. Make Well 16 “primary” well while Well 9 becomes “secondary”.

   a. Well 9 is physically located in a poor location as it abuts the backyards of residential housing. Once Well 16 comes on-line, the SCADA (Supervisory Control and Data Acquisition) settings on Well 9 should be altered to cycle the well off for most of the winter months and to cycle on the well during periods of higher demand (generally mornings and evenings in the Spring, Summer and Fall). This will reduce neighbor complaints and will allow the City to utilize Well 9 in a backup mode of operation.

   b. Operations staff have since altered SCADA settings for the entire water system and alternate well cycling accordingly.

5. Continue building backbone system on ½-mile and 1-mile grid network

   a. The most important aspect of a distributed system is multiple paths of delivery. In a grid network, flow redundancy is ensured should a portion of the system be down for repairs or retrofit. By connecting all wells to a 12” grid system (on the 1-mile backbone), the City of Kingsburg is allowing for fire flows to be achieved at all points in the system at that all wells contribute equally in delivering system demands.

  b. *The City has ensured that water mains within major streets have been constructed with 12" water pipeline.*

6. Conduct annual or bi-annual pump energy tests.

   a. Pump impellers wear over time and efficiency is lost. It is important to test the well on a regular basis to maximize energy savings. While the total lift within the City of Kingsburg is relatively small and energy consumption, when compared to other communities, is also reduced, the City should take proactive steps to ensure that each well is operating within efficiency standards and energy consumption is optimized.

   b. *The City has not conducted energy tests on a scheduled basis.*

7. Utilize the SCADA system to control and monitor system operation.

   a. Water systems should be adjusted seasonally to ensure that pumps are cycled and operated on a normative basis. Operations staff should spend more time working with the SCADA system to create seasonal settings. In addition, during the winter months, different pumps and settings should be evaluated. A separate SCADA evaluation should be conducted to determine operational schedules during different seasons.

   b. *Operations staff have, and continue to alter SCADA settings to ensure that all wells are utilized and cycled on a regular basis.*

Chapter 2
System Data Collection

2.1 Existing System

The City of Kingsburg is relatively flat with elevations ranging from 288' to 310' above sea level. Given such flat terrain, the system is operated as a single pressure zone.

The existing water distribution system is shown in Figure 1 and contains seven (7) wells with approximately 78 miles of distribution piping, ranging in size from 2" to 12" in diameter as shown in Table 1. The City contains a 12" backbone grid which interconnects the well system to the water network and is shown as Figure 1.

City of Kingsburg
Exist Pipe Sizes and Lengths

Diameter (in)	Length (ft)	Length (mi)	% Total
2	3,332	0.63	0.80%
4	32,169	6.09	7.73%
6	69,945	13.25	16.80%
8	142,770	27.04	34.30%
10	5,033	0.95	1.21%
12	163,010	30.87	39.16%
Total	416,259	78.84	

Table 1 – Existing Water Pipe Sizes and Length Breakdown

The well system provides all water supply for the City of Kingsburg. Information regarding each well is provided in Table 2. Overall, the maximum production capacity of the well system is approximately 7,500 gpm at 50 psi (see Table 2).

City of Kingsburg
Well Information

Identification	State	Static Water Depth (ft.)	Depth at Drawdown (ft.)	Ground Elevation (ft.)	Total Lift @ 60 psi (ft.)	Max Design Flow Rate (gpm)	Efficiency (%)	Backup Power
Well 9	Constant Speed	34.3	71.0	301.2	209.5	800	78	
Well 10	Constant Speed	36.4	75.0	296.9	213.5	800	71	
Well 12	Constant Speed	34.0	72.0	295.8	210.5	1,500	79	Yes
Well 13	VFD	37.8	76.0	297.6	214.5	1,000	69	Yes
Well 14	VFD	40.0	74.0	293.9	212.5	1,000	71	
Well 15	Constant Speed	34.7	70.0	289.7	208.5	1,200	79	
Well 16	VFD	Unk.	74.0	300.1	212.5	1,200	n/a	
						7,500		

Table 2 – City of Kingsburg Existing Well Information

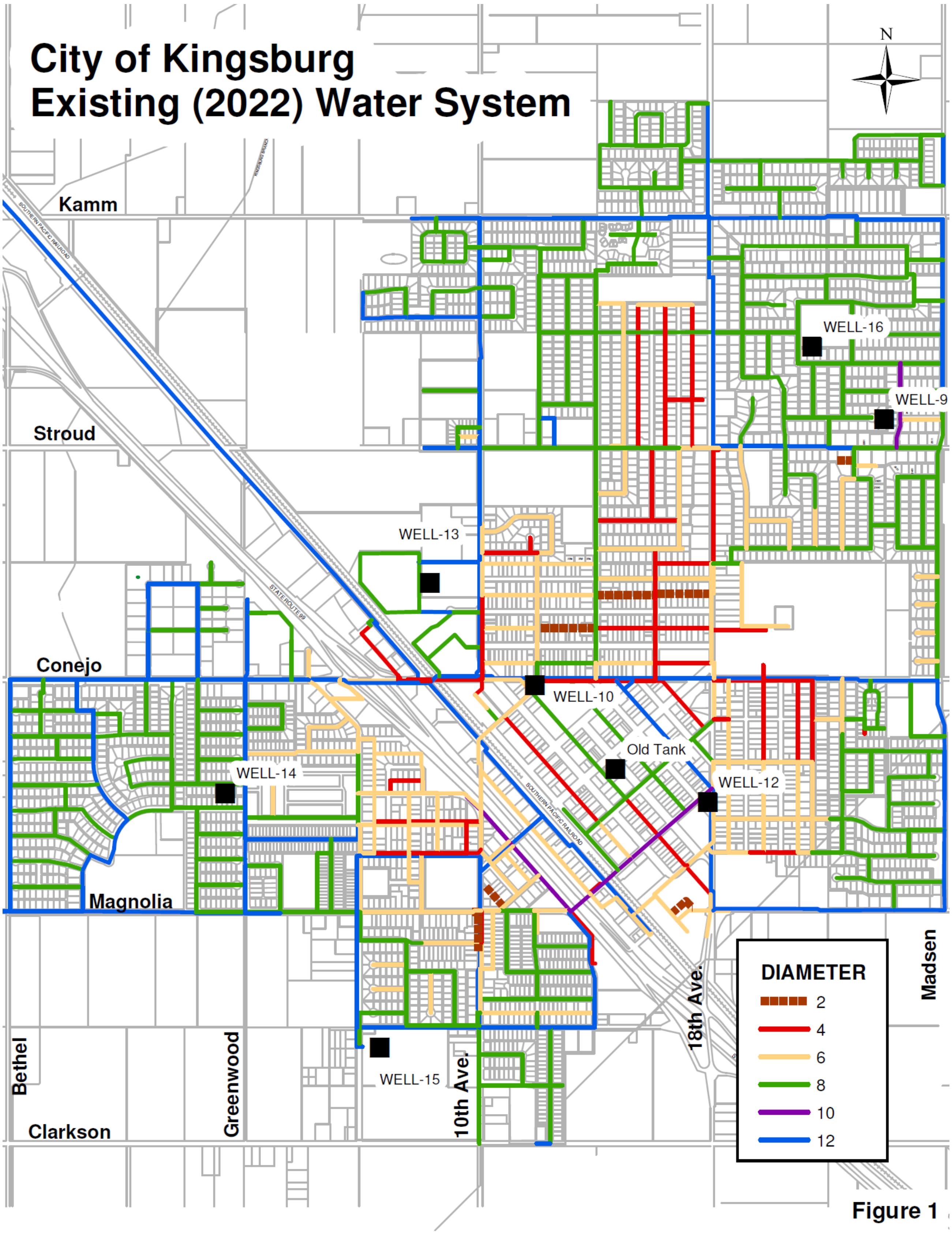


Figure 1 – City of Kingsburg Existing Water System

An elevated water storage tank is located in the center of town but was abandoned in 2010 and is presently functioning as an historical landmark.

SCADA

The City of Kingsburg operates and maintains a Supervisory Control and Data Acquisition (SCADA) system to assist in the management and control of the water system. The SCADA system is capable of gathering and recording system data that is more readily available for system analysis. Table 3 provides the current (Spring 2022) SCADA operational settings for each well site and has been sorted by the 'Order On' sequence for each well.

City of Kingsburg
SCADA Settings (Well Sites)

WELL #	Type	Elevation	ALARM LOW (psi)	START (psi)	TARGET (psi)	SHUT OFF (psi)	ALARM HIGH	ALARM LOW (hgl)	START (hgl)	SHUT OFF (hgl)	ORDER ON	ORDER OFF
16	VFD	300.1	32	44	46	62	56	374	402	443	1	6
10	Static	296.9	32	44		55	60	371	398	424	2	2
13	VFD	297.6	32	42	52	56	60	371	395	427	3	4
9	Static	301.2	30	40		65	55	370	394	451	4	7
15	Static	289.7	33	44		56	58	366	391	419	5	1
12	Static	295.8	32	40		61	60	370	388	437	6	5
14	VFD	293.9	32	40	49	57	60	368	386	425	7	3

Table 3 – City of Kingsburg Existing SCADA Operational Settings

An explanation of each column of Table 3 is provided as follows:

1) Well – The City of Kingsburg Well Site Identification number.

2) Type – Wells can be operated as 'Static', meaning that when operational, they run at full power or 'VFD', meaning that the speed of the motor operating the pump at the bottom of the well speeds up and slows down, dependent upon the discharge pressure experienced at the well site. Wells 13, 14 and 16 all operate in this manner and serve as a cushion to the water system when operational, reducing large pressure swings that can be experienced in an all 'Static' water system.

3) Elevation – The ground elevation at each well site. While Kingsburg is relatively flat, the ground elevation is important when considering the 'On', 'Off' and 'Target' pressure settings for each well site.

4) Alarm Low – The pressure setting at which system operators will be notified that a low water pressure is being experienced (ie, a large water main break during a hot summer day when all wells are operational.)

5) Start – The discharge pressure setting that the each well will turn on and become operational.

6) Target – Only relevant to VFD well sites, the pressure setting that electronically informs the motor at the specific well site to speed up or slow down in order to maintain the designated set

pressure. In periods of high demand, the VFD will operate at 100% capacity and other system wells cycle on at their own low pressure settings.

7) Shut Off – The pressure setting at which the well site will turn off.

8) Alarm – The pressure setting at which system operators will be notified that a high water pressure is being experienced (ie, sudden shut off of fire hydrants after a large fire, system blow off valves have become non-operational)

9) HGL – The Hydraulic Grade Line of the previously described settings. These values are measures in feet above sea level and simply add the ground elevation of each well site to the various pressure settings.

10) Order On/Off – The order for each well site to turn on and turn off, taking into account the ground elevation and the activating pressure setting.

It is the responsibility of the water system operators to monitor the SCADA settings and to rotate the order of operation throughout the year to moderate usage of equipment at each well site. City staff have done a commendable job of not only cycling well sites seasonally, but also ensuring that Static and VFD well sites alternate and are not stacked in the SCADA sequence, ensuring that potential system pressure swings are normalized.

Groundwater Supply

The City of Kingsburg water system is served entirely by groundwater. As shown in Figure 2, the City of Kingsburg is an independent water utility and is a member of the South Kings Groundwater Sustainability Agency (SKGSA) as mapped by the Sustainable Groundwater Management Act (SGMA).

A total, maximum day pumping capacity of the seven (7) city wells is approximately 10.8 million gallons per day (assuming all wells produce 7,500 gpm and run continually for 24 hours). Presently, the City consumes approximately 2.89 million gallons per day on an average day and approximately 5.94 million gallons on a maximum day (see Table 5). The ability of the City to utilize the existing well system to satisfy all future growth in lieu of drilling new wells is predicated entirely on how well the City water distribution system can adequately service a new growth area for operational and fire flows, as discussed further in this report.

Appendix A of this report has been added as informational background and shows that the groundwater table has decreased from a depth of 35 feet in the year 2000 to a depth of approximately 80 feet in the Spring of 2022. This lowering of the water table could be representative of the many studies and articles illustrating that the western United States is experiencing a multi-year drought - and that drops in the local water table are also commensurate with decreases in other, regional groundwater aquifers. The localized drop in the groundwater table could also be the result of more surface waters being diverted away from the Kings River via the six (6) primary irrigation canals upstream of Kingsburg in lieu of maintaining normalized flows in the Kings River - up to and through Riverland RV Resort on Highway 99. The reduction of flows in the historic river channel of the Kings River would likely cause changes in the groundwater table of Kingsburg as the river channel, when flowing, serves as groundwater recharge of the local aquifer.

System Demands

Pump record data for the City of Kingsburg has been collected between the years of 2010 to 2021 and is provided in Table 4. According to the data, the City of Kingsburg has reduced its per capita water consumption from approximately 316 gallons/per capita/per day (gpcd) in 2013 to about 238 gpcd in 2021 (see Figure 3). This is a reduction of approximately 25% and is commensurate with amounts experienced in other California communities which can further be attributed to improved water metering, public education, water conservation and continuous changes to the plumbing code.

The data further show that during the summer of 2011, the average water consumption was roughly 150 million gallons per month, but that by 2019, that number had been reduced to approximately 100 million gallons per month. While that number increased in the summer of 2021 to about 120 million gallons, it illustrates that landscaping and outdoor irrigation practices have been altered by the citizens of Kingsburg and that citizens and businesses have normalized their water conservation efforts.

The data also show that the City pumped a minimum amount of 29 million gallons in January of 2016 and a maximum amount of 178 million gallons in July of 2011. While indoor water usage is typically constant, this change in volume is illustrative of the amount of water used for irrigation and landscaping. For this water model update, a nominal value of 240 gpcd has been used in evaluating average day water demands for both the existing system model and for the future build out of the water system. A maximum day peaking factor of 2.06 was calculated by dividing the maximum month value of 178.10 mgd by the average month calculation of 86.65 mgd.

City of Kingsburg
Monthly Water Production (million gallons)
Years 2010 - 2021

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
January	35.60	42.40	55.90	49.90	62.60	45.30	28.92	36.11	37.00	33.66	48.62	50.92
February	39.40	41.70	53.90	50.00	49.20	39.90	34.09	31.85	46.68	31.51	49.45	47.78
March	61.90	61.30	71.10	87.20	69.20	67.10	41.32	50.05	49.47	30.56	60.76	69.17
April	73.30	97.00	84.80	117.10	88.30	78.79	63.91	66.63	71.79	33.81	56.70	89.07
May	76.30	115.30	136.40	143.60	119.60	86.80	89.69	89.64	84.48	63.13	91.25	105.22
June	150.00	149.60	159.90	161.80	136.30	101.90	111.13	102.14	104.47	74.97	111.67	132.70
July	157.40	178.10	168.50	170.10	141.60	104.39	129.00	103.97	152.36	90.76	119.90	118.48
August	165.90	166.60	167.40	162.40	131.40	95.86	122.00	109.44	98.53	102.45	125.94	117.91
September	135.90	152.00	145.80	140.90	118.20	78.17	89.90	79.16	83.07	105.98	105.62	111.28
October	102.90	115.00	121.60	119.60	107.00	78.60	89.70	82.67	85.39	80.16	95.48	93.27
November	67.00	69.20	69.60	79.20	61.10	42.55	58.27	58.90	61.77	75.35	72.48	68.06
December	49.90	57.80	46.40	62.60	45.00	36.60	42.89	43.54	48.79	57.51	57.35	46.79
Annual Total	1115.50	1246.00	1281.30	1344.40	1129.50	855.97	900.82	854.09	923.80	779.85	995.22	1050.65
Annual Ac-Ft	3,423	3,824	3,932	4,126	3,466	2,627	2,764	2,621	2,835	2,393	3,054	3,224
Population	*11,640*	*11,698*	*11,756*	*11,814*	*11,872*	*11,930*	*11,987*	*12,045*	*12,103*	*12,161*	*12,219*	*12,277*
Averages												
Monthly	92.96	103.83	106.78	112.03	94.13	71.33	75.07	71.17	76.98	64.99	82.94	87.55
Daily	3.10	3.46	3.56	3.73	3.14	2.38	2.50	2.37	2.57	2.17	2.76	2.92
GPCD	266	296	303	316	264	199	209	197	212	178	226	238

Max. Month	178.10
Min. Month	28.92
Avg. Month	86.65
Avg. Day	2.89
Avg. GPCD	242
Peaking Factor	2.06
Max. Day	5.94

Table 4 – City of Kingsburg Monthly Water Well Production with Water Demand Calculation

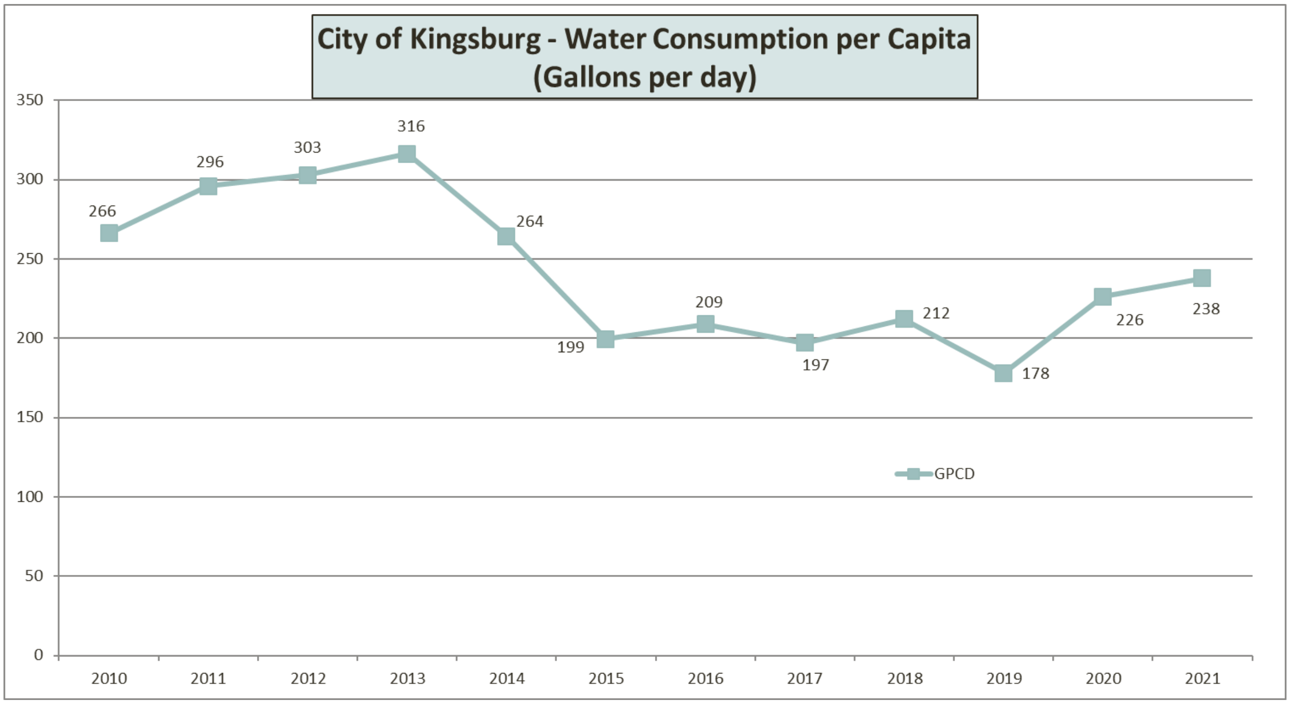


Figure 3 – Annual Average per Capita Water Consumption (gpcd)

Chapter 3
Existing Water System Simulations

3.1 Introduction

Prior to determining future hydraulic modeling scenarios, the computer model was calibrated to existing conditions in which three separate scenarios (i.e. conditions) were analyzed. The first scenario was Existing – Average Day Demand while the second scenario evaluated Existing – Maximum Day Demand. A third condition, modeling Existing – Minimum Day Demands, was also analyzed to evaluate system operations during months of reduced water consumption. Each analysis and relevant hydraulic information is provided herein.

System demands utilized in each scenario are provided in Table 5 and were derived via GIS software. Demands were allocated in the hydraulic model by intersecting the Demand Area Polygons with the underlying Land Use as shown in Figure 4. System nodes were then populated with demands generated by the total land uses within each demand area polygon. As shown in Figure 5, approximately 1,852 acres of the City of Kingsburg have been developed with the various land use categories as provided in Table 5. As previously referenced, the City of Kingsburg supplies approximately 2.89 million gallons on a typical day (Average Day Demand) which has been further broken down by land use type. The average day demand of 2.89 mgd translates into an average day demand of approximately 2,005 gpm while the maximum and minimum day demands have been calculated as being 4,131 gpm and 1,003 gpm, respectively. The computer model was summarily loaded with these values and then evaluated for an extended period simulation.

City of Kingsburg
Existing Land Use Distribution and System Demand

Usage Type	Description	Water Duty (mgd/acre.)	Water Duty (gpm/acre)	Area (acres)	Avg Day Demand (mgd)	Max Day Demand (mgd)	Min. Day Demand (mgd)
CC	Commercial	0.0012	1.728	53.7	0.0645	0.1328	0.0322
CC/MU	Commercial/Mixed Use	0.0012	1.728	66.0	0.0792	0.1631	0.0396
HC/MU	Highway Commercial/Mixed Use	0.0015	2.160	38.6	0.0580	0.1194	0.0290
HD	High Density	0.0032	4.608	41.6	0.1330	0.2740	0.0665
HI	Highway Industrial	0.0010	1.440	210.4	0.2104	0.4334	0.1052
LD	Low Density	0.0014	2.016	911.4	1.2760	2.6285	0.6380
LI	Light Industrial	0.0018	2.592	62.1	0.1118	0.2302	0.0559
LI/MU	Light Industrial/Mixed Use	0.0018	2.592	50.8	0.0914	0.1883	0.0457
MD	Medium Density	0.0021	3.024	226.7	0.4760	0.9805	0.2380
RCO	Registered Community Use	0.0024	3.456	161.4	0.3872	0.7977	0.1936
			Totals	***1,822.6***	***2.8874***	***5.9479***	***1.4437***
			GPM		***2,005***	***4,131***	***1,003***
					Peaking Factor =	2.06	

Table 5 – City of Kingsburg Water System Demand by Existing Land Use

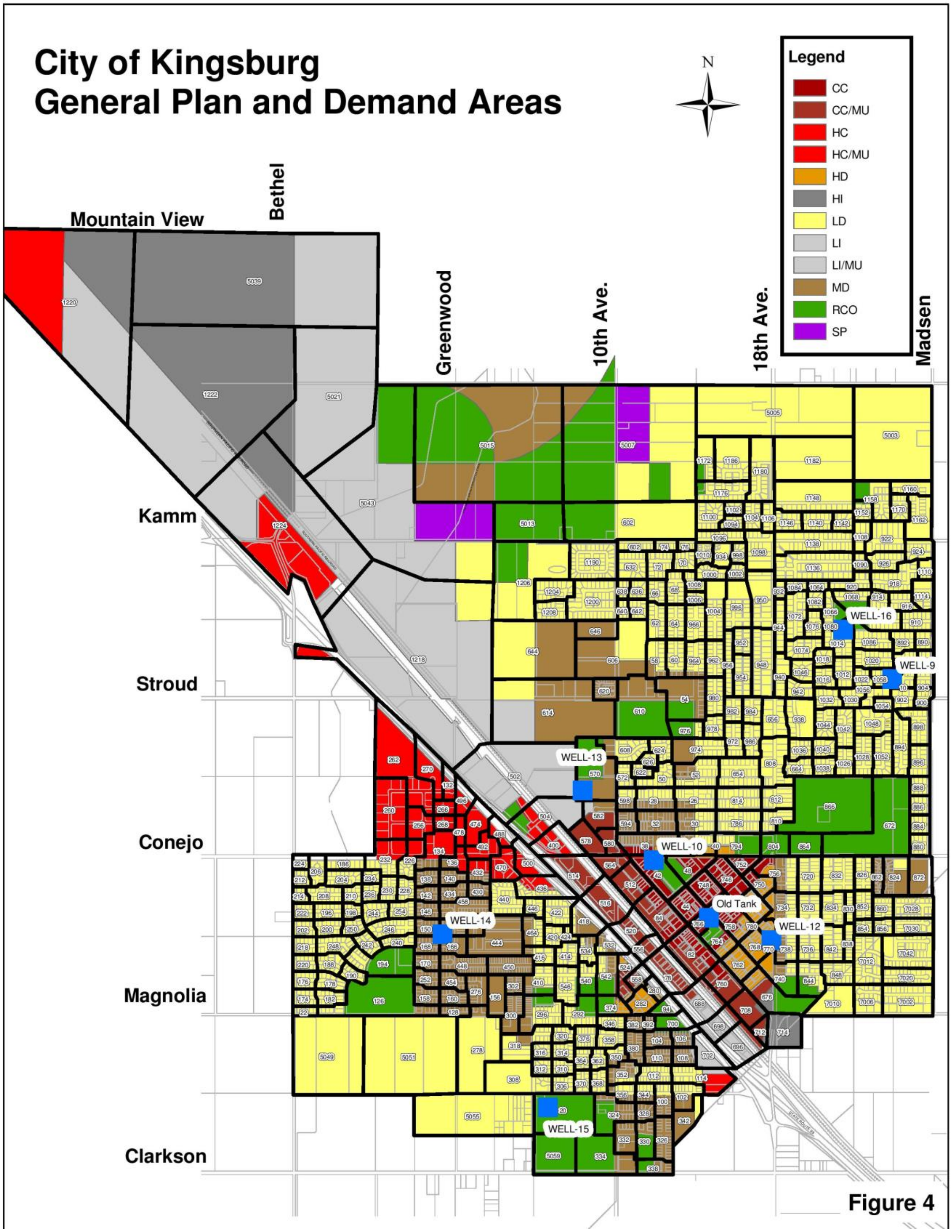


Figure 4 – City of Kingsburg – General Plan with Water Demand Tributary Areas

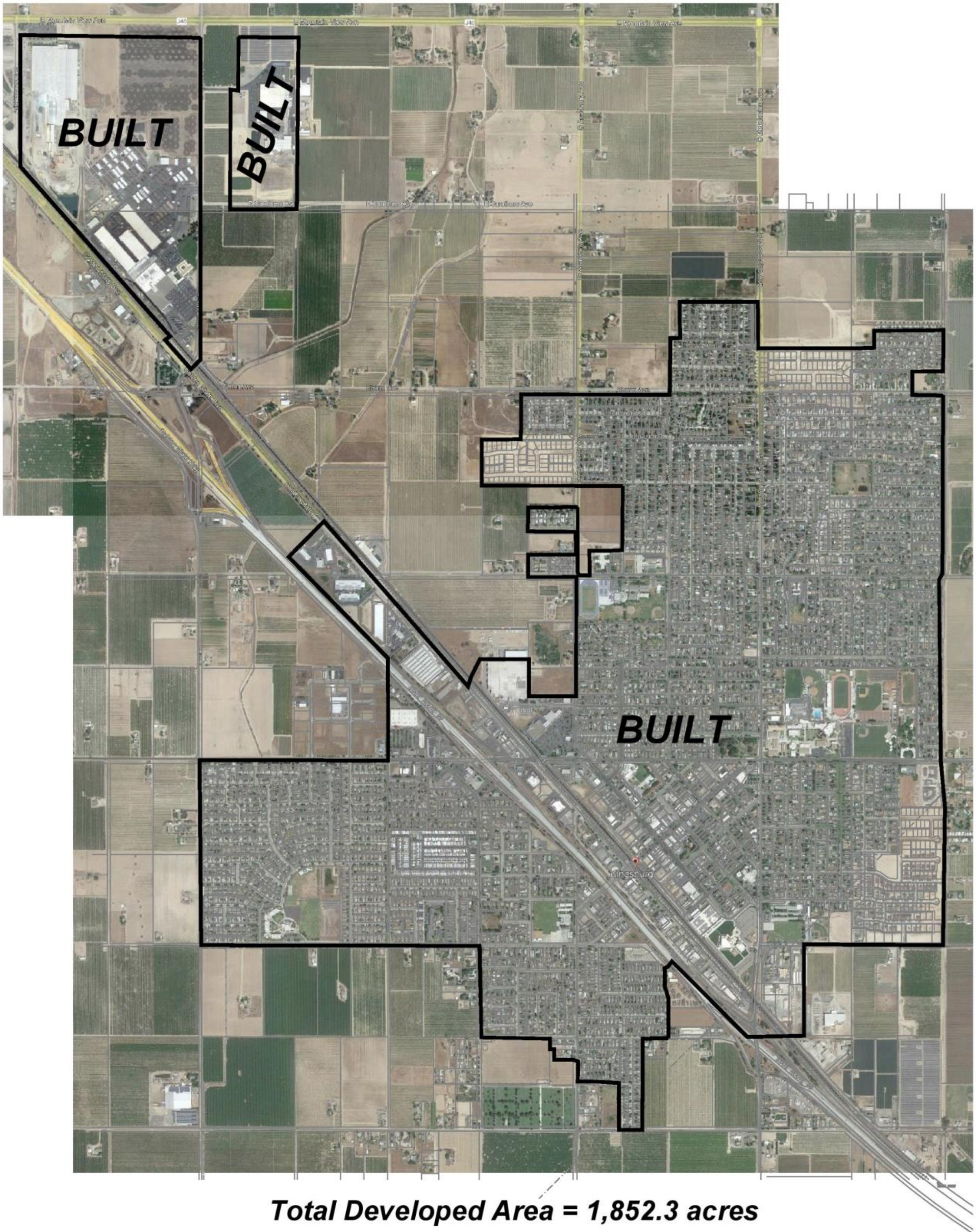


Figure 5 – City of Kingsburg Existing Developed Area

3.2 Existing – Average Day Simulation

The analysis of this scenario determined that the system operates efficiently under normal conditions (2,005 gpm). System pressures varied from a low of 49 psi to a high of 58 psi. Worst case pipe flows were specific to the various 2" and 4" pipes that ultimately require replacement. All other elements of the water system, such as well production, system demands, pressures and flows, all operate within design parameters. No mitigation is required in an Existing – Average Day Demand scenario. Figure 6 illustrates normal well operations during an Average Day demand simulation.

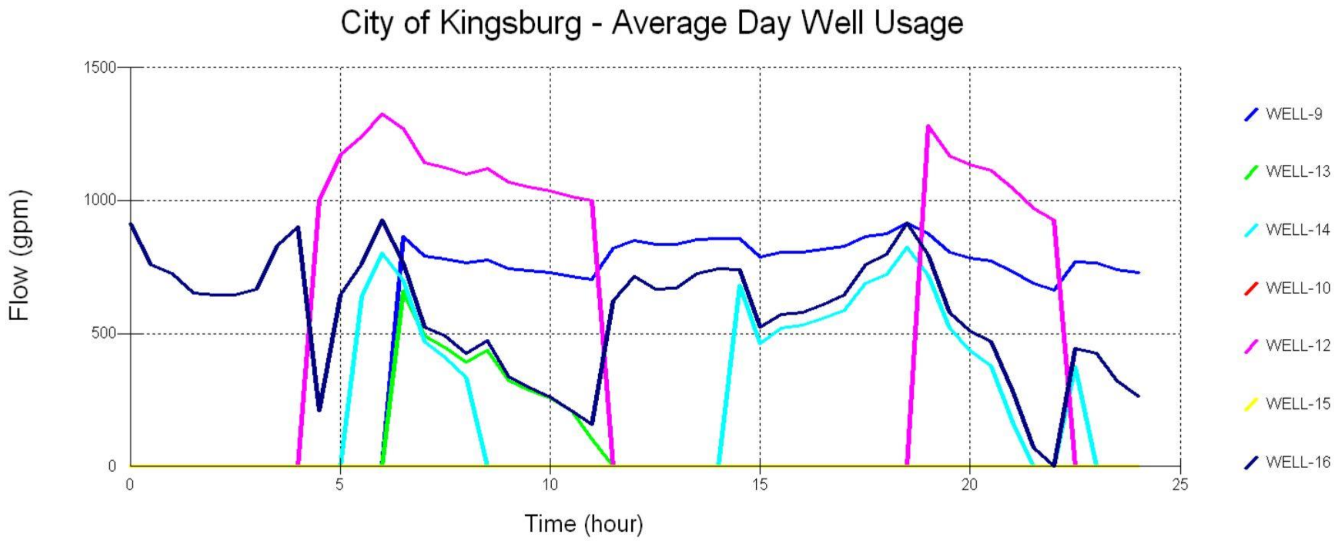


Figure 6 – City of Kingsburg – Average Day Demand Well Usage

3.4 Existing – Maximum Day Simulation

The maximum day demand represents peak water usage during the summer months. Is also this time of year the likelihood of a fire is increased due to dry, arid conditions. Thus, while the results of a maximum day demand are informative, it is the fire flow simulation that illustrates the ability of the water system to deliver both system flows and fire flows that protect the health and welfare of the general public

The analysis of this scenario determined that the system operates efficiently under maximum day conditions (4,131 gpm). During peak periods of the day, all pumps are operating and system pressures are maintained between a low of 52 psi to a high of 60 psi. These values vary slightly from the average day demand due to operational settings (SCADA) that were provided to the hydraulic model. However, they do demonstrate that system pressures are being maintained at all times of the day.

During this model simulation, pipe and pump flows increased throughout the system (2,005 gpm on an average day to 4,131 gpm on a maximum day). However, all pipe flows and velocities were found to be within normal operational parameters.

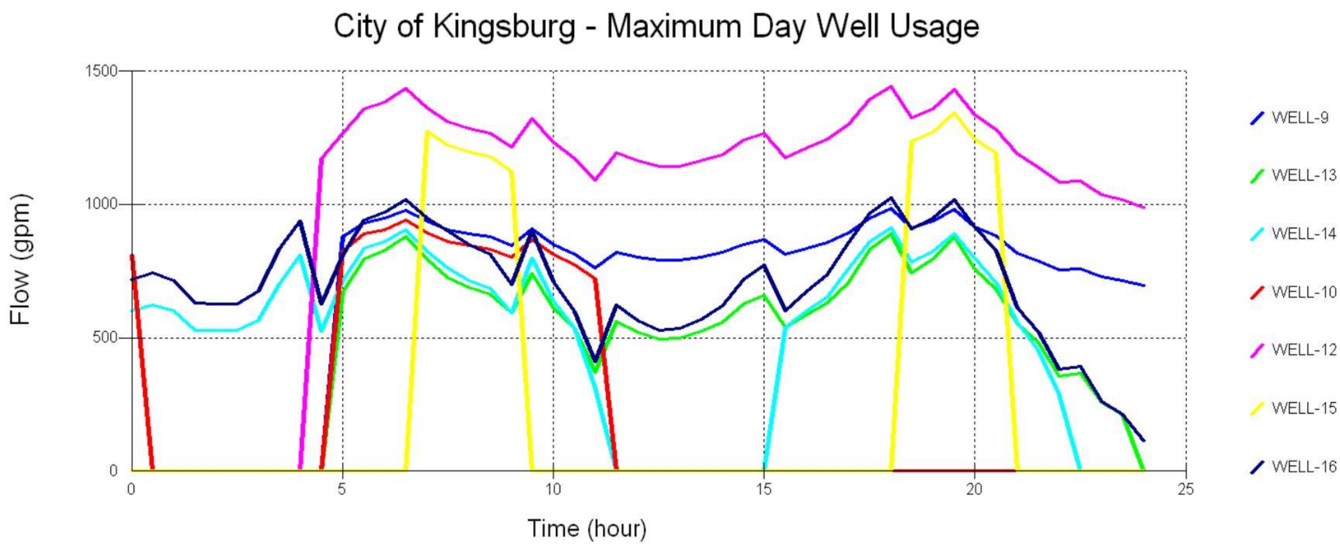


Figure 7 – City of Kingsburg – Maximum Day Demand Well Usage

Figure 7 shows well performance during a maximum day simulation. Since Wells 13, 14 and 16 are variable frequency drives, flow rates change throughout the day to compensate for changes in system demand. All other wells cycle on and off during periods of demand variation. In water systems, it is important to recognize the impact pressure settings on wells have on cycling and ensure that one well is not overloaded. The goal is to vary SCADA settings to promote well cycling at different intervals and to share system loads.

Fire Flow Simulation

Fire flows needs vary from one community to another. Flow requirements are dictated by the underlying land use – which can vary from 1,200 gpm for single family residential housing unit to 2,500 gpm for an industrial or very large commercial center. Flow rates, if not determined by the local fire service provider, can be determined by the International Services Organization (ISO) or the American Water Works Association (AWWA) Manual M31 – Distribution System Requirements for Fire Protection. Table 6 represents modeled fire flows at the various land uses within the City of Kingsburg.

City of Kingsburg
Fire Flow Demands by Land Use

Usage Type	Description	Fire Flow (gpm)	Duration (hour)	Supply Req'd (gal)
CC	Commercial	2,000	2	240,000
CC/MU	Commercial/Mixed Use	2,000	2	240,000
HC	Highway Commercial	2,000	2	240,000
HC/MU	Highway Commercial/Mixed Use	2,000	2	240,000
HD	High Density	2,500	3	450,000
HI	Highway Industrial	2,500	2	300,000
LD	Low Density	1,200	2	144,000
LI	Light Industrial	2,000	3	360,000
LI/MU	Light Industrial/Mixed Use	2,000	3	360,000
MD	Medium Density	1,800	2	216,000
RCO	Registered Community Use	1,200	2	144,000
SP	Semi Public	1,500	2	180,000

Table 6 –Fire Flows by Land Usage

The modeling software utilized for the City of Kingsburg allows a fireflow analysis in which each node in the water distribution system is given a fire flow demand and modeled accordingly. The resulting simulation results illustrate which nodes in the system dropped below optimal pressures and flows when a fire demand was modeled in the system. Such an analysis helps in the identification of system deficiencies such as undersized pipe or insufficient looping in providing the necessary fire flow and in maintaining system pressures.

City of Kingsburg
Maximum Day + Fire Flow Simulation
1,200 gpm Fire Flow Demand

ID	Static Demand (gpm)	Static Pressure (psi)	Fire-Flow Demand (gpm)	Residual Pressure (psi)	Available Flow @Hydrant (gpm)	Available Flow Pressure (psi)	Reason	Cross Streets
378	0.000	58.97	1,200	-7844.86	67.79	20.00	End of 2" Pipe	Roosevelt and 10th
710	0.000	58.16	1,200	-5014.61	84.81	20.00	End of 2" Pipe	Kern and 18th
388	0.000	58.56	1,200	-4736.20	88.15	20.00	End of 2" Pipe	Lewis and Church
1062	0.000	56.28	1,200	-2883.08	110.76	20.00	End of 2" Pipe	Stroud and 22nd
702	0.002	58.14	1,200	-327.02	335.32	20.00	End of 4" Pipe	Rayser and 14th
590	0.000	56.87	1,200	-117.44	530.07	20.00	End of 4" Pipe	Sierra and Simpson
952	5.122	55.16	1,200	-93.25	553.55	20.00	Middle of 4" Pipe	Klepper and 18th
958	0.000	54.28	1,200	-80.12	567.61	20.00	End of 4" Pipe	Klepper and 18th
994	0.000	55.64	1,200	-84.60	572.29	20.00	End of 4" Pipe	Klepper and 18th
956	6.331	54.82	1,200	-81.92	581.68	20.00	Middle of 4" Pipe	Klepper and 18th
950	14.739	55.14	1,200	-79.59	588.43	20.00	Middle of 4" Pipe	Klepper and 18th
996	12.767	54.71	1,200	-74.00	596.88	20.00	Middle of 4" Pipe	Klepper and 18th
864	13.343	57.12	1,200	-84.18	599.59	20.00	End of 4" Pipe	Kingburg H.S.
626	2.572	57.11	1,200	-64.31	644.74	20.00	Along 4" pipe	Windsor and Winter
84	13.077	56.98	1,200	-66.30	646.13	20.00	End of 4" Pipe	Ellis and California
686	0.000	58.18	1,200	-32.93	760.34	20.00	6" Dead End	Simpson and Earl
954	7.992	55.21	1,200	-23.35	782.66	20.00	End of 4" Pipe	Klepper and 18th
948	16.215	55.64	1,200	-23.64	791.59	20.00	Along 4" pipe	Klepper and 18th
722	0.000	54.76	1,200	-2.21	893.86	20.00	Fixed	Kingburg H.S.
866	203.249	53.63	1,200	-27.59	905.68	20.00	End of 4" Pipe	Kingburg H.S.
676	25.233	58.14	1,200	-7.17	925.21	20.00	6" Dead End	Kern and 18th
704	0.000	57.71	1,200	-2.99	931.06	20.00	Along 4" pipe	Kern and 18th
712	2.644	58.59	1,200	-2.39	943.87	20.00	Needs Replacement	Kern and 18th

Table 7 – City of Kingsburg – Areas of Deficient Fire Flows

Table 7 contains the output of a 1,200 gpm fire flow analysis and shows all nodes in the system where a flow of at least 1,000 fire flow could not be obtained. The last two columns of this table provides the location and the reason of the deficiency.

Figure 8 is a graphic illustration of Table 7 and shows the deficient flow nodes as being RED. The pipe colors connected to the deficient hydrant flow nodes are shown as being a red pipe (2" diameter), an orange pipe (4" diameter) and a yellow pipe (6" diameter). As the graphic shows, the city has specific areas that require upgrading for fire protection services which should be placed on a multi-year capital improvement program.

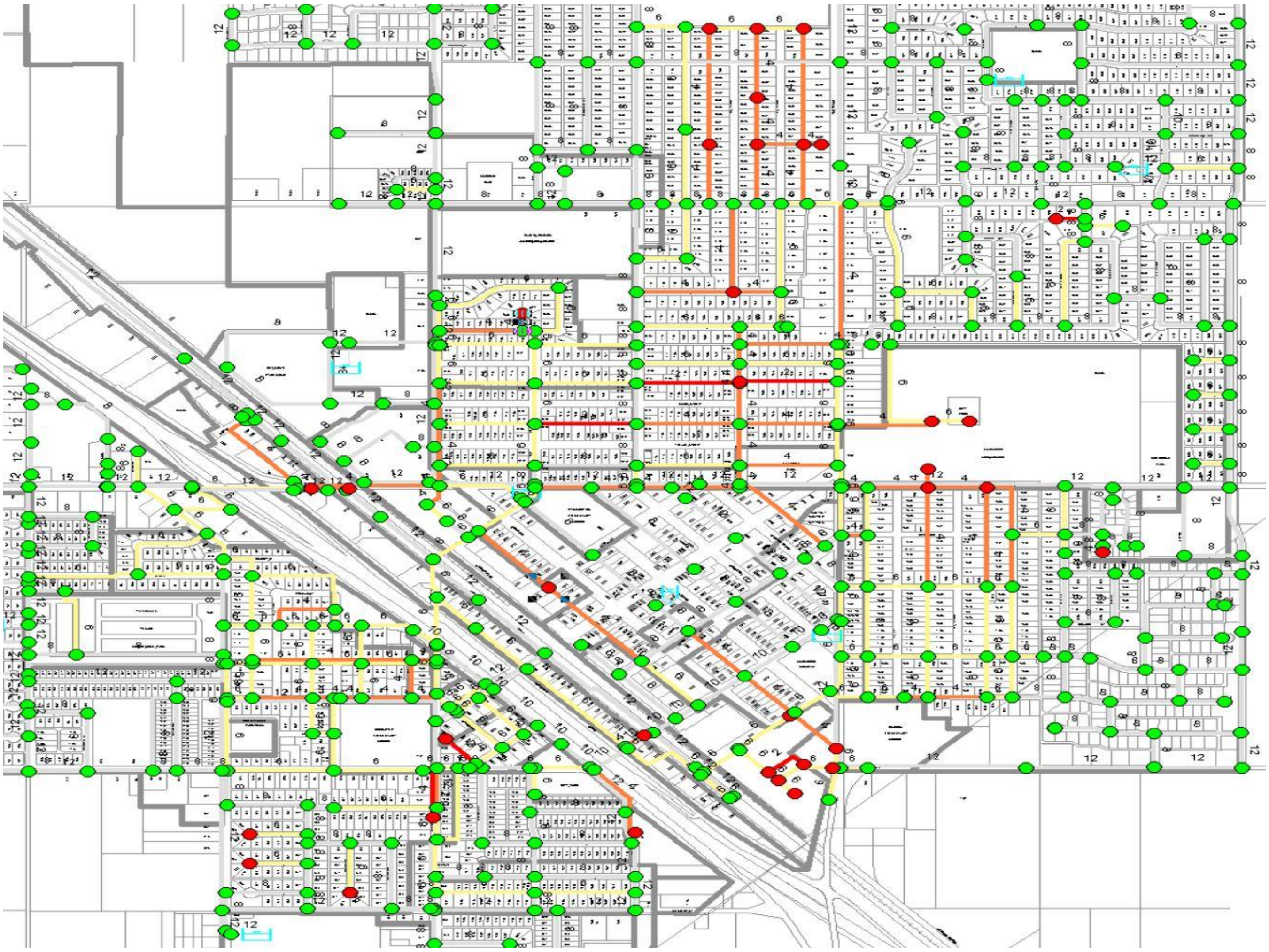


Figure 8 – City of Kingsburg – Areas of Low Fire Flows

Very Large Fire Demands

The next step in evaluating a Maximum Day + Fire Flows scenario is to analyze those areas of the City where high fire flow demands are required. Land uses such as Commercial, Industrial and Schools per Table 5 should be evaluated to determine whether sufficient infrastructure is in place to provide the necessary fire flow demands. However, in terms of risk management, consideration should be given to fire sprinklers and their role in fire suppression during a fire event for those structures equipped with sprinklering devices.

Delivering fire flows greater than 2,000 gpm requires adequate looping and piping infrastructure to be present and may require additional, on site water storage facilities. As fire demands increase, so too must the size of the water distribution infrastructure. For school, large commercial and industrial land uses, a 12” diameter pipe should be installed and looped around such a land use. The 12” pipe ensures that system pressures remain at safe levels and that adequate flows are provided during a fire event.

Chapter 4
Future Water System Simulations

4.1 Introduction

The primary purpose of a water model update is determining future capital improvements required to serve the ultimate water system. The City of Kingsburg has an approved general plan which has the city expanding from a present build-out of approximately 1,823 acres to a future build-out of approximately 3,235 acres (+177% - shown as Figure 9).

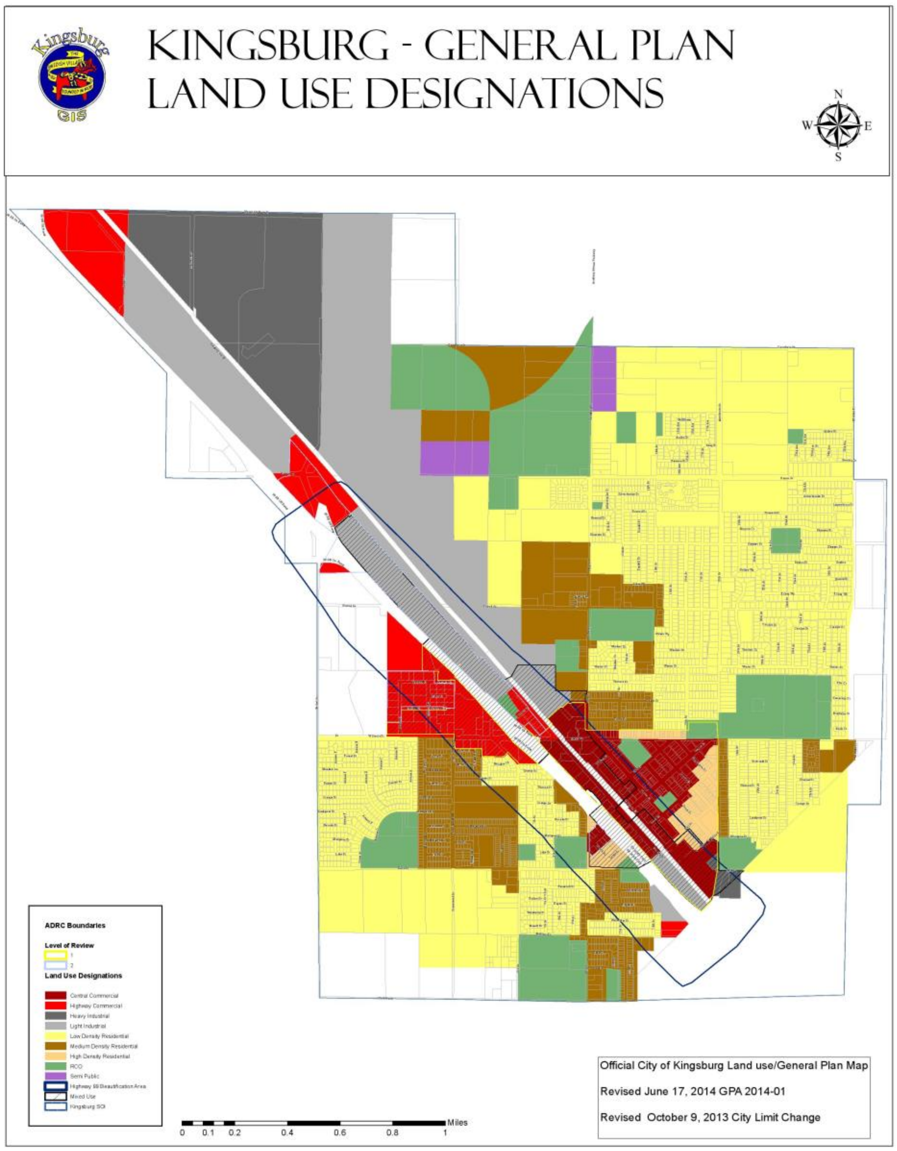


Figure 9 – City of Kingsburg – General Plan

System demands utilized in modeling the future, general plan build out are provided in Table 8 which were derived via GIS software. Demands were allocated in the same fashion as described in Section 3.1, excepting that new demand nodes which were digitized for the future water system and were given 'demand areas' in the GIS that were then intersected with the underlying land uses and then applied to the hydraulic model. As shown in Table 8, the total average day demand applied to the model was approximately 5.39 mgd while the maximum day demand was 11.11 mgd, respectively. Each model was then evaluated for an extended period simulation.

City of Kingsburg
Future Land Use Distribution and System Demand

Usage Type	Description	Water Duty (mgd/acre.)	Water Duty (gpm/acre)	Area (acres)	Average Day Demand	Max. Day Demand	Min. Day Demand
CC	Commercial	0.0012	1.728	53.7	0.0645	0.1328	0.0322
CC/MU	Commercial/Mixed Use	0.0012	1.728	66.0	0.0792	0.1631	0.0396
HC	Highway Commercial	0.0015	2.160	94.8	0.1422	0.2930	0.0711
HC/MU	Highway Commercial/Mixed Use	0.0015	2.160	81.3	0.1220	0.2513	0.0610
HD	High Density	0.0032	4.608	41.6	0.1330	0.2740	0.0665
HI	Highway Industrial	0.0010	1.440	245.3	0.2453	0.5053	0.1227
LD	Low Density	0.0014	2.016	1,351.8	1.8926	3.8987	0.9463
LI	Light Industrial	0.0018	2.592	444.3	0.7998	1.6476	0.3999
LI/MU	Light Industrial/Mixed Use	0.0018	2.592	73.8	0.1329	0.2738	0.0665
MD	Medium Density	0.0021	3.024	370.1	0.7772	1.6011	0.3886
RCO	Registered Community Use	0.0024	3.456	374.3	0.8983	1.8505	0.4492
SP	Semi Public	0.0028	4.032	37.6	0.1053	0.2170	0.0527
			Totals	***3,234.8***	***5.3923***	***11.1082***	***2.6962***
			GPM		***3,745***	***7,714***	***1,872***

Table 13 - General Plan Average and Maximum Day Demands by Land Use

As further provided Table 13, the future maximum day demand of 11.11 mgd translates into a maximum day production requirement of 7,714 gpm. As referenced in Table 2 in Section 2.1 of this report, the current, maximum well capacity of the existing well system is 7,500 gpm, thus requiring additional wells prior to the full build out of the City general plan.

Figure 10 has been created by overlaying the City of Kingsburg General Plan over aerial mapping obtained from Google Earth. This image has been provided to show the size and the extent of the overall General Plan on the existing city and surrounding agricultural areas.

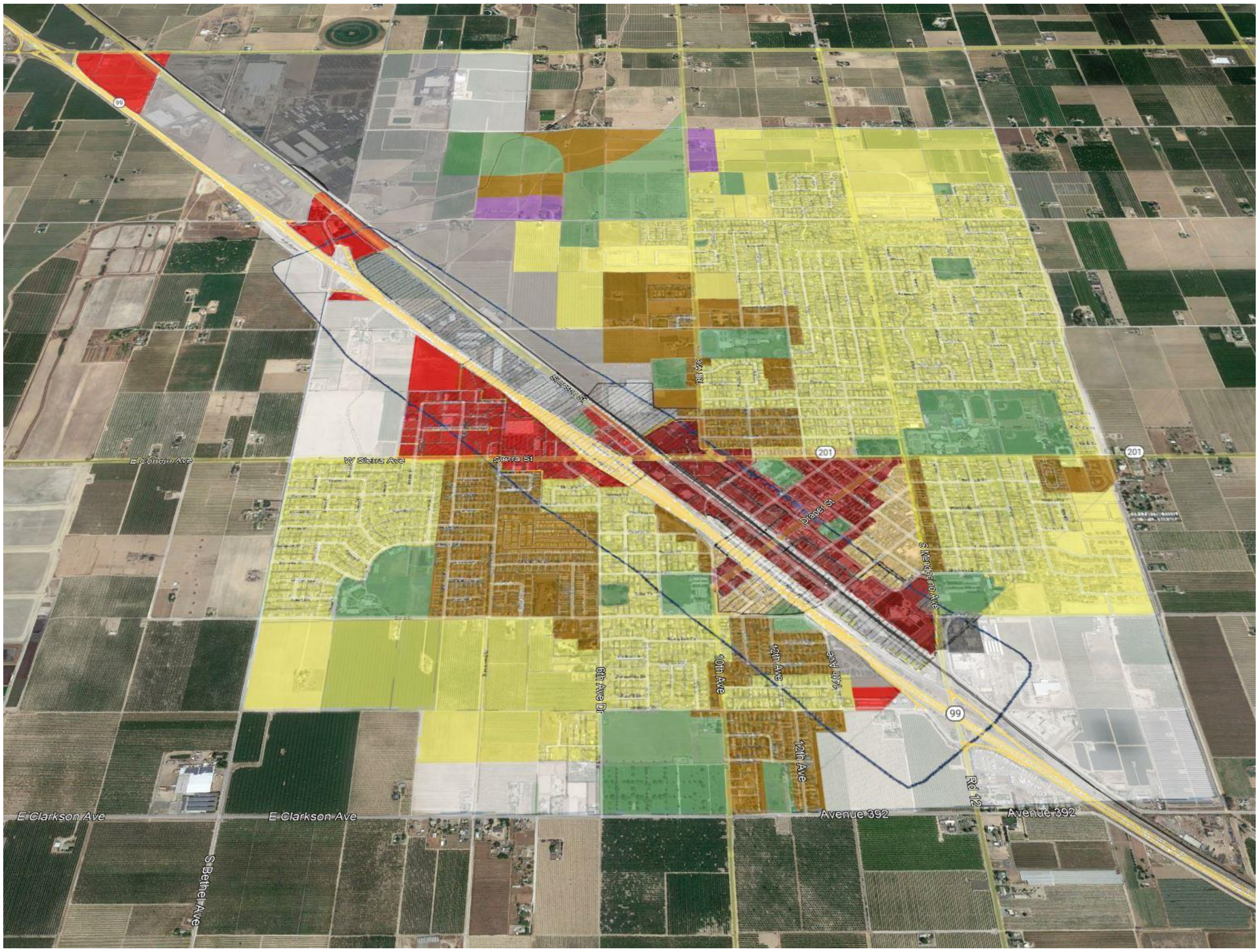


Figure 10 - City of Kingsburg General Plan on Google Earth Image

4.2 Future System – Average Day Analysis

The analysis of this scenario determined that improvements will be required to ensure that the water distribution system operates efficiently. Table 14 shows the increases between the current day models and the future, general plan build-out models.

City of Kingsburg
General Plan - Future Water Demand

	Avg. Day Demand (gpm)	Max. Day Demand (gpm)
Exist	2,005	4,131
Future	3,745	7,714
Increase	1,740	3,584

Table 14 - General Plan Water Demands (w/ Increase Over Existing)

As provided in Table 14, the City will require an additional 1,740 gpm of average day supply and 3,584 gpm of maximum day supply in servicing the build out of the City general plan. As the city does not possess any surface water contracts, it is understood that all new water supply will be exclusively groundwater and it expected that for the City to construct additional wells to accommodate the full build-out of the General Plan.

The analysis of this scenario determined that with the addition of the necessary capital improvements as referenced in Section 5 of this report, City of Kingsburg water system will operate at a sufficient level of service and that no other significant capital facilities are required.

4.3 Future System – Maximum Day Analysis

As provided in Table 14, a full build out of the City general plan during a maximum day demand will require a continuous water supply of 7,714 gpm (more than 200 gpm higher than the full production of the existing 7 wells serving the City). During peak hours of a future, maximum day, the City of Kingsburg will require as much as an additional 6,000 gpm. As the City does not have any large water storage tanks, the entirety of this supply will be provided by new groundwater wells.

Figure 11 illustrates the addition of three new wells (Well 17, Well 18 and Well 19) in order to accommodate this increased demand. Each well as been modeled as being able to provide between 1,500 gpm and 2,000 gpm. Even with the addition of three new wells, the simulation results indicate that a 4th well could be required as backup and fire redundancy during periods of increased demand during the early morning and late afternoon hours of the day.

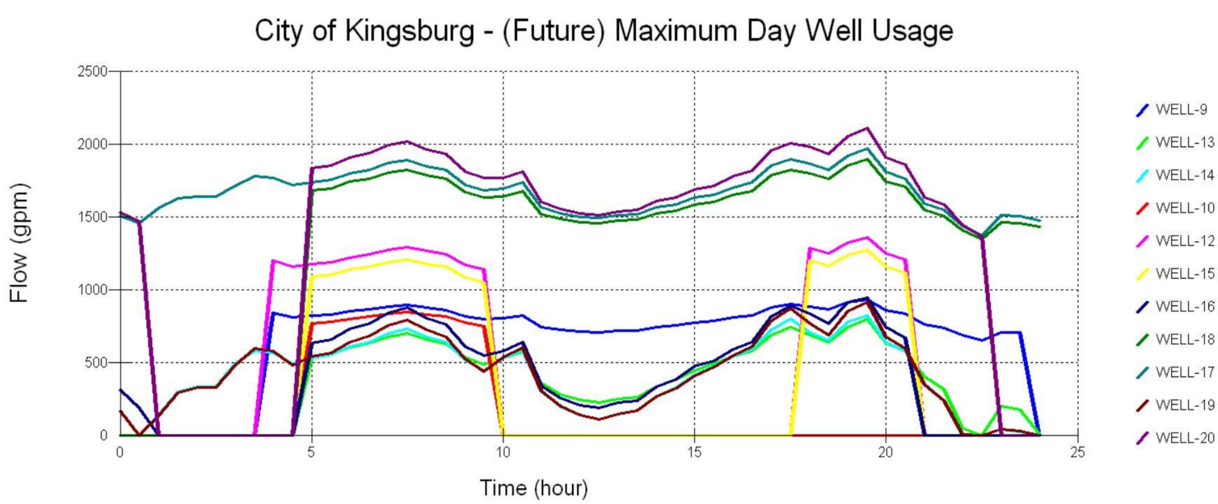


Figure 11 - City of Kingsburg General Plan – Maximum Day Water Demand

Fire Flow Simulation

As shown in Figure 12, expansion of the water system requires that a backbone network of 12" water lines be installed at ½ mile intervals. This type of network grid allows for sufficient water supply and fire protection which translates into no fire flow deficiencies as it relates to the future, expanded regions of the water system. The existing deficiencies identified in Section 3.4 of this report are still applicable until such time the underlying backbone water system is improved in the affected areas.

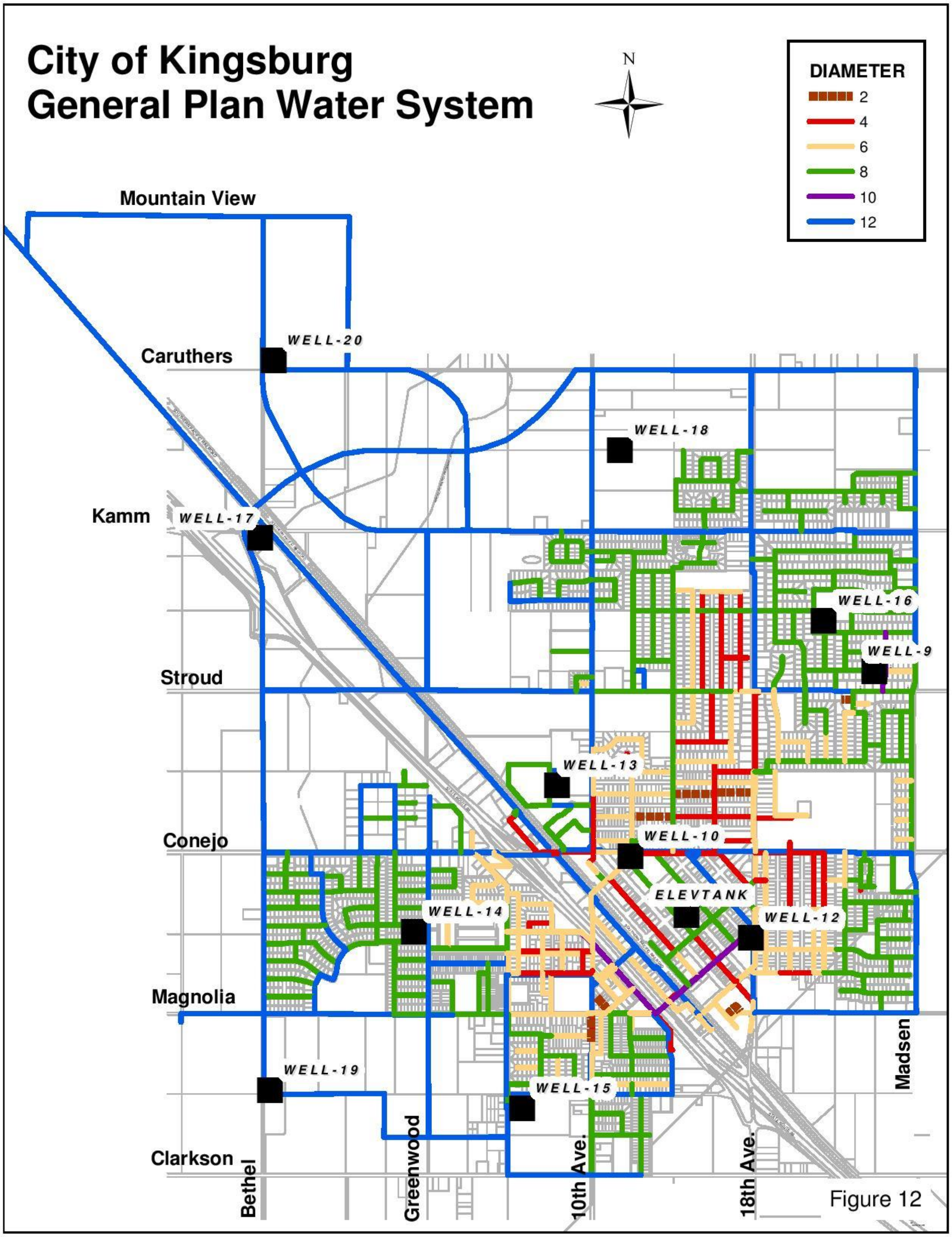


Figure 2 - City of Kingsburg General Plan Build Out Water System

Chapter 5
Capital Improvement Plan

5.1 Existing System Improvements

The existing water distribution system, with the recent addition of Well #16, is operating efficiently. As previously discussed and provided in Table 7 of this report, various portions of the existing water system require upgrade for fire protection purposes. It is recommended that the City begin a multi-year capital improvement program for the replacement of deficient water lines which could coincide with the City's pavement overlay and maintenance program.

5.2 Future System Improvements

Analysis of the future build out of the City of Kingsburg General Plan indicates that at least three new wells will be required. This figure is dependent upon the attainable yield achieved at each well site which has projected as being at least 1,800 gpm per site. Table 15 provides a list of future facility upgrades that are additionally illustrated in Figure 12

City of Kingsburg
Future System - Capital Improvement Plan

	Item	Street	Location	New or Parallel	Size	Type
1	*Well 17*	*Simpson Ave*	*On Kamm Ave alignment*	New	1,800 gpm	Static
2	*Well 18*	*Academy Ave*	*1/2 mile /o Kamm*	New	1,800 gpm	VFD
3	*Well 19*	*Mehlert Ave*	*Near Bethel Ave.*	New	1,800 gpm	Static
4	*Water Lines*	*City-wide*	*1/2 mile cross streets*	New	12" PVC	DR-18

Table 15 - General Plan Capital Improvement Projects

In the event that well yields fall below the estimated values, then the city will need to construct additional wells on a per unit basis as further described below.

Timing of Projects

One aspect of capital facility planning is determining the timing of new facilities construction. In review, the City of Kingsburg currently has seven (7) operational wells which produce a maximum of 7,500 gpm (10.8 mgd), a developed land impact of 1,823 acres (per Table 5), a population of approximately 12,000 citizens which consume an average of 240 gallons per person/per day (2.89 mgd average day and 5.9 mgd maximum day).

A simple method of development impacts is on a 'per acre' basis. At present, the City of Kingsburg has constructed one (1) well (~1,000 gpm) for every 260 acres of development. This ratio equates to approximately 3.85 gpm of new well capacity for every one (1) acre developed. With consideration given to existing and future development, Table 16 has been provided to assist the City with future, capital improvement decision making with regards to new well sites.

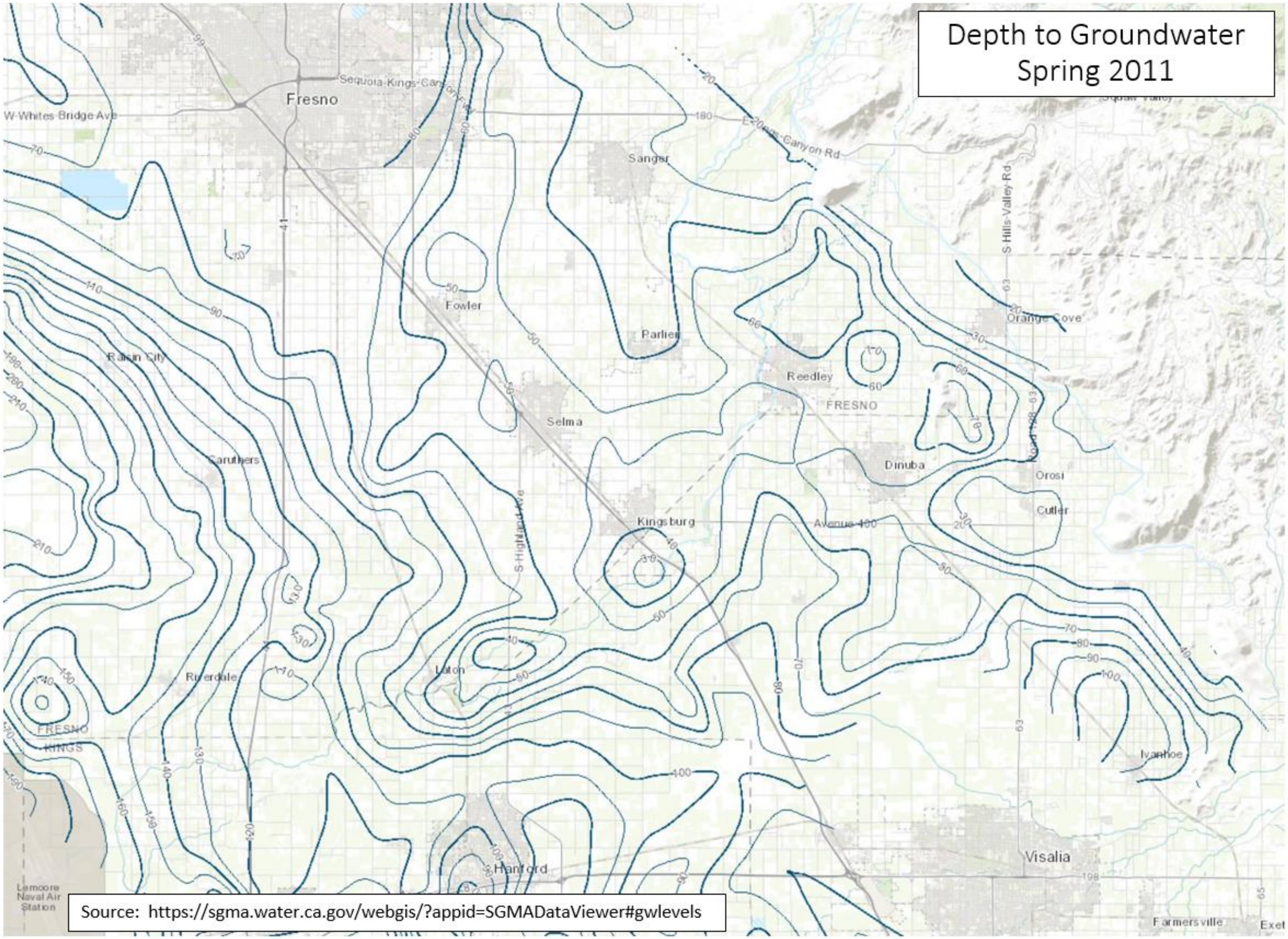
City of Kingsburg
Future System - Capital Improvement Phasing

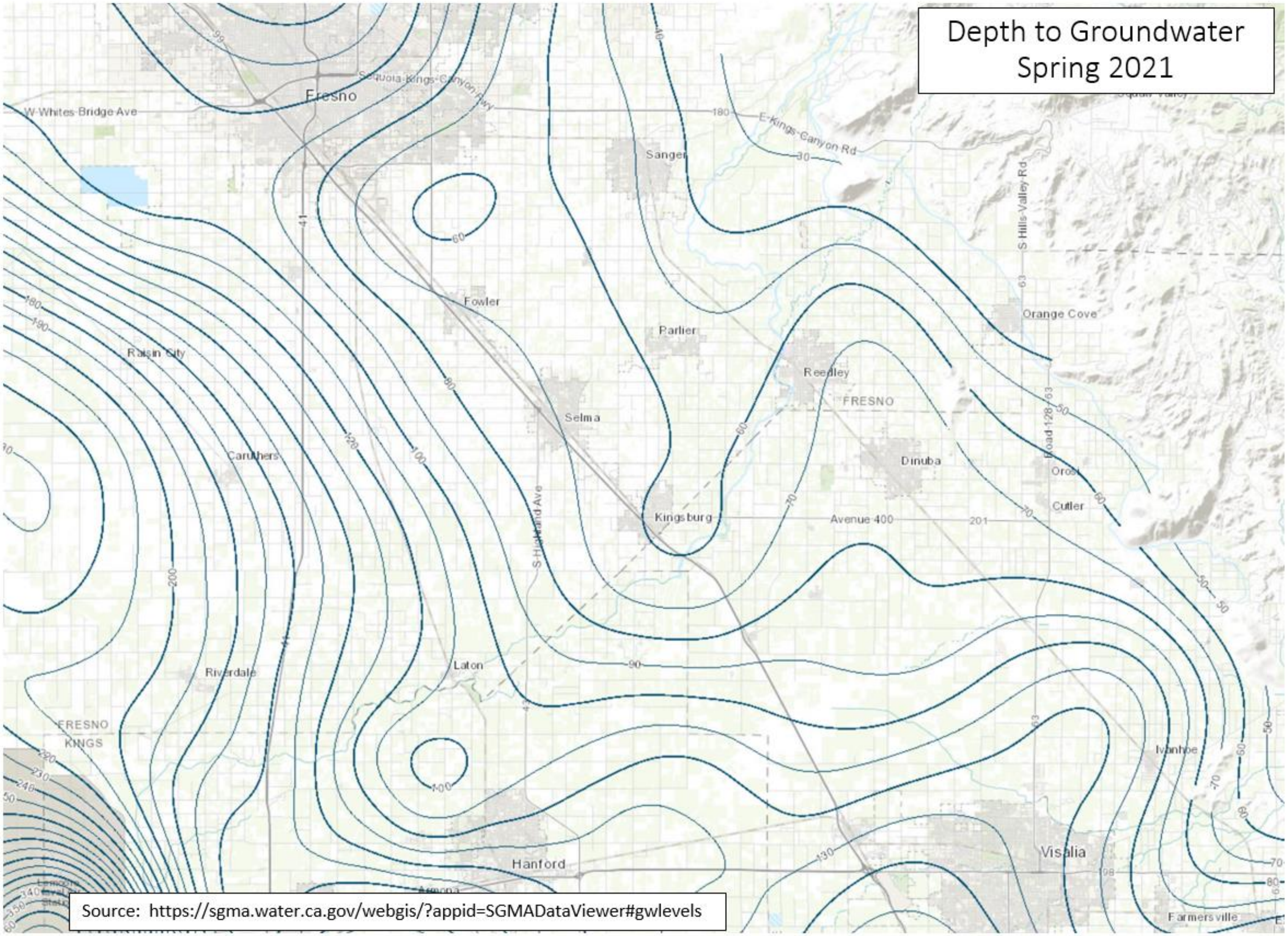
	Item	Developed Impact	Well Capacity
1	*Well 17*	*2,000 acres*	1,800 gpm
2	*Well 18*	*2,400 acres*	1,800 gpm
3	*Well 19*	*2,800 acres*	1,800 gpm

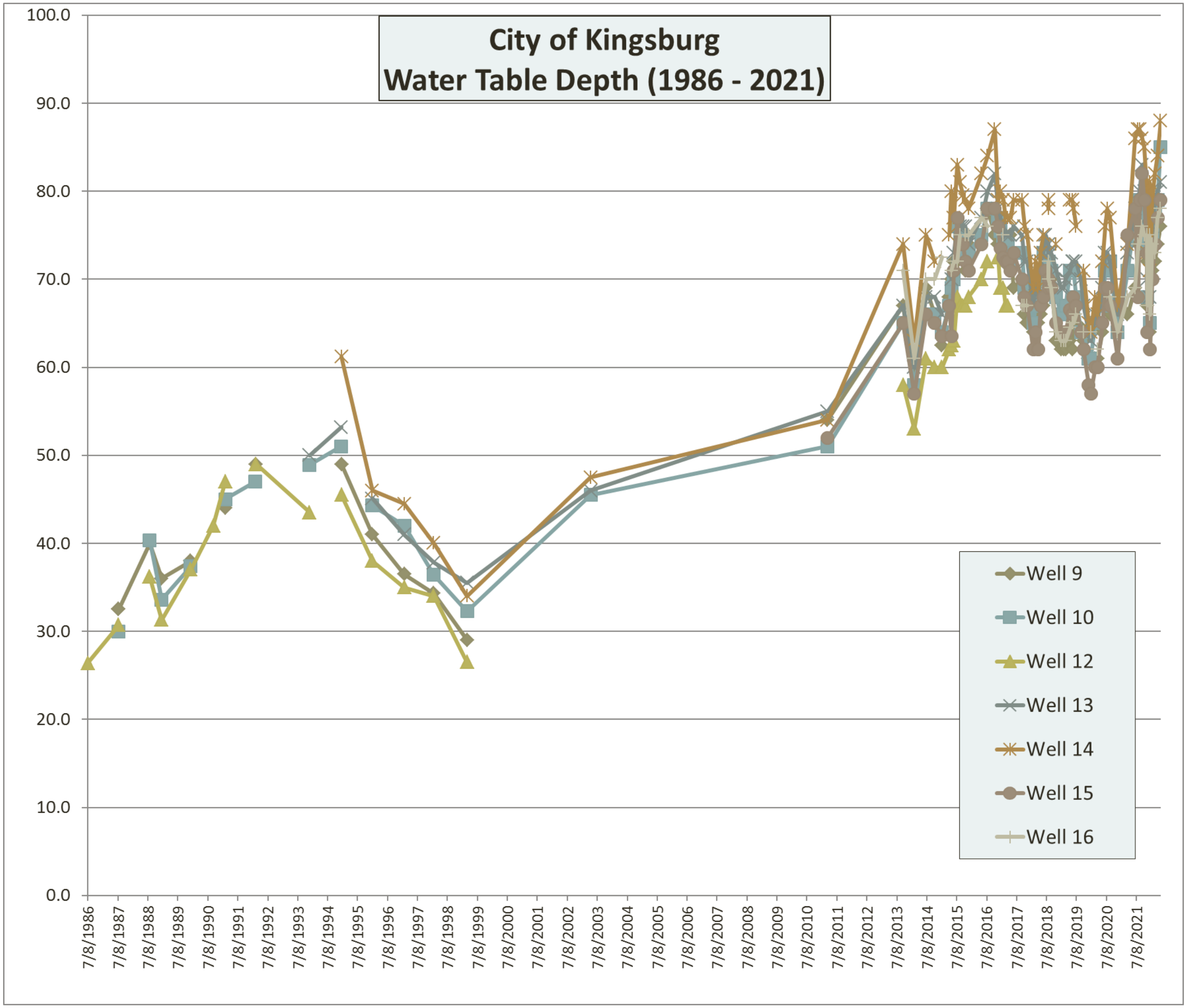
Table 16 - General Plan Capital Improvement Project Phasing

As example, Well 17 should begin construction at the permitting of the 2,000 (gross) acre of development impact and should be operational within the next 50 to 75 acres of development impact. Likewise, Well 18 should begin construction at the 2,400 acre of development impact and become operational soon thereafter. Should proven well production fall below the expected values provided in Table 16, then the City should recalculate this table and adjust accordingly.

APPENDIX A


Depth to Groundwater
Spring 2011
Fresno
Sanger
Fowler
Parlier
Reedley
Selma
Dinuba
Orosi
Cutler
Orange Cove
Kingsburg
Caruthers
Raisin City
Riverdale
Laton
Hanford
Visalia
Ivanhoe
Farmersville
Lemoore Naval Air Station
W Whites Bridge Ave
Sequoia-Kings Canyon Fwy
E Kings Canyon Rd
S Hills Valley Rd
S Highland Ave
Avenue 400
FRESNO
KINGS
Source: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels


Depth to Groundwater
Spring 2021
Fresno
W Whites Bridge Ave
E Kings Canyon Rd
Sanger
Fowler
Parlier
Reedley
Raisin City
Selma
Dinuba
Orange Cove
Orosi
Cutler
Caruthers
Kingsburg
Avenue 400
S Highland Ave
S Hills Valley Rd
Road 128
FRESNO
KINGS
Riverdale
Laton
Hanford
Visalia
Ivanhoe
Farmersville
Source: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels


City of Kingsburg
Water Table Depth (1986 - 2021)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
7/8/1986
7/8/1987
7/8/1988
7/8/1989
7/8/1990
7/8/1991
7/8/1992
7/8/1993
7/8/1994
7/8/1995
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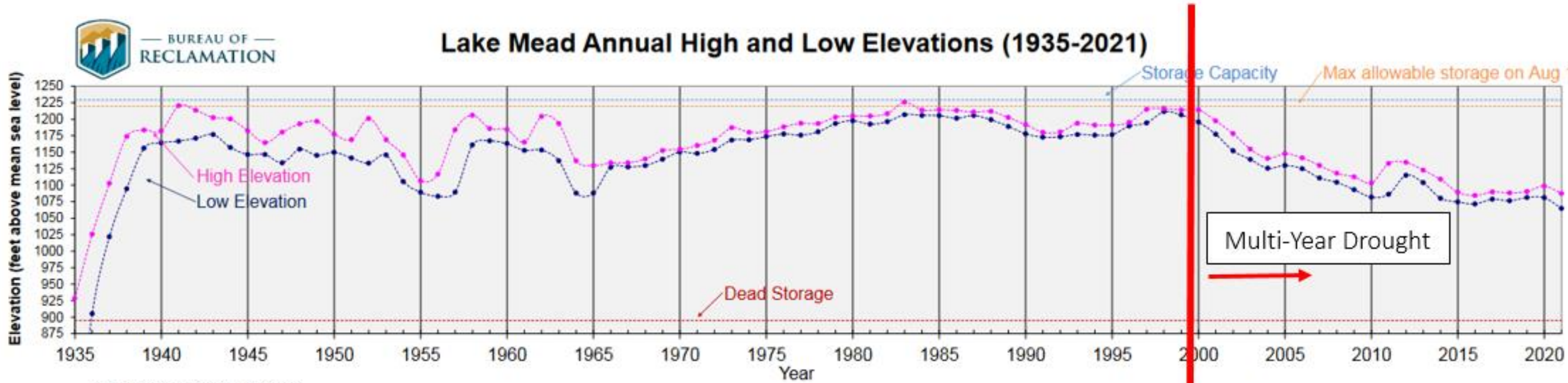
7/8/2014
7/8/2015
7/8/2016
7/8/2017
7/8/2018
7/8/2019
7/8/2020
7/8/2021
Well 9
Well 10
Well 12
Well 13
Well 14
Well 15
Well 16

Lake Mead
Historical Water Levels



Note: Low Elevation for 1935 is 673.50 feet

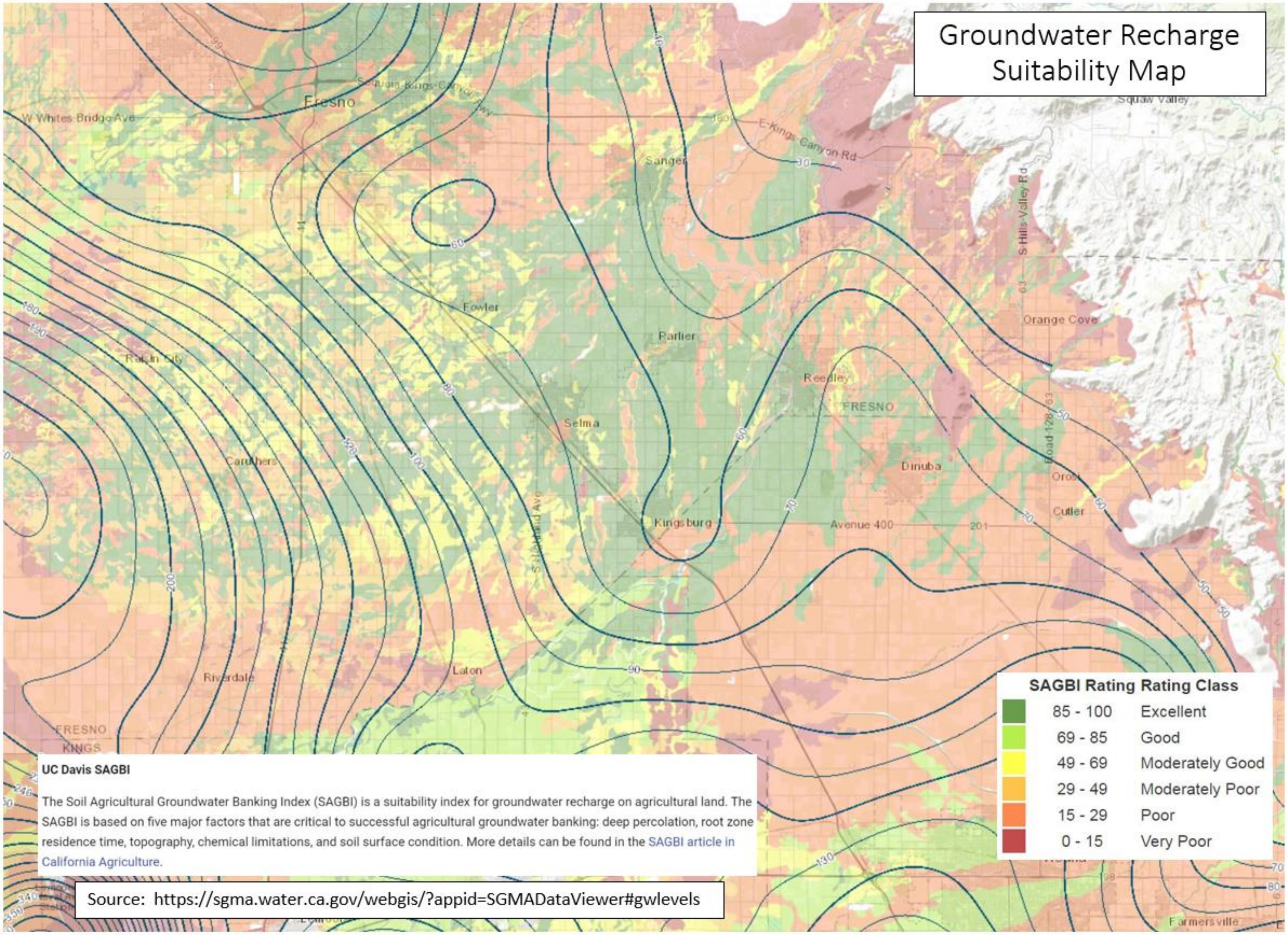
Year	Date	Time	Low Elev	Date	Time	High Elev
1935	3-Feb	2400	673.50	31-Jul	2400	928.45
1936	14-Apr	2400	905.20	10-Sep	2400	1025.87
1937	5-Feb	2400	1021.90	28-Jul	2400	1102.88
1938	17-Feb	0001	1094.61	29-Jul	0001	1173.56
1939	18-Mar	0001	1156.10	2-Jul	0001	1183.50
1940	5-Apr	0001	1164.21	3-Jul	0700	1182.21
1941	16-Feb	2400	1166.74	30-Jul	0730	1220.46
1942	28-Mar	2400	1171.04	8-Jul	1200	1213.46
1943	5-Apr	1900	1176.71	14-Jul	1200	1202.45
1944	8-Apr	1900	1157.17	19-Jul	0930	1200.36
1945	26-Apr	2400	1146.54	21-Aug	0430	1182.50
1946	19-Apr	2100	1146.50	7-Jul	1500	1164.32
1947	26-Apr	0300	1133.90	2-Sep	0600	1180.27
1948	30-Mar	2100	1154.45	11-Jul	1800	1192.80
1949	15-Apr	2400	1145.18	31-Jul	1800	1196.68
1950	13-Apr	2400	1149.95	24-Jul	0300	1177.66
1951	11-May	2400	1141.19	13-Aug	1200	1169.01
1952	3-Apr	2100	1133.24	17-Jul	0900	1201.13
1953	31-Dec	2400	1145.78	1-Jan	2400	1169.13
1954	31-Dec	2400	1105.48	1-Jan	0300	1145.83
1955	22-Apr	2400	1089.39	7-Jul	0600	1106.63
1956	26-Apr	2100	1083.19	9-Jul	0600	1116.84
1957	20-Apr	0900	1089.48	9-Sep	1200	1184.11
1958	19-Apr	2400	1161.00	7-Jul	0600	1205.93
1959	31-Dec	1800	1167.11	1-Jan	0600	1185.93
1960	11-Mar	2400	1162.97	5-Jul	0600	1184.19
1961	18-May	1800	1152.78	2-Jan	0600	1165.21
1962	9-Feb	2400	1153.16	23-Jul	1200	1204.21
1963	31-Dec	2400	1136.93	1-Jan	2400	1193.19
1964	30-Dec	2400	1088.09	1-Jan	2400	1136.93
1965	3-Apr	2400	1088.07	31-Dec	2400	1129.74
1966	17-Sep	2400	1127.18	19-Feb	1200	1133.84
1967	22-Nov	2400	1127.75	13-Feb	1200	1133.85
1968	1-Jan	0001	1129.84	31-Dec	2400	1139.65
1969	16-Jan	2400	1139.38	31-Dec	2400	1152.50
1970	20-Aug	2400	1150.39	21-Jan	1200	1154.18
1971	2-Apr	2400	1148.05	31-Dec	2400	1160.13
1972	25-May	2400	1153.97	31-Dec	2400	1168.35
1973	1-Jan	0001	1168.35	7-May	0600	1187.01
1974	15-Jun	0600	1168.81	4-Feb	0600	1180.23
1975	29-May	1200	1173.61	14-Oct	0600	1181.03
1976	10-Oct	1200	1177.58	31-Dec	2400	1188.27
1977	6-Jul	1200	1175.80	6-Feb	0600	1193.82
1978	1-Jan	2400	1180.82	31-Dec	2400	1193.31
1979	1-Jan	2400	1193.37	26-Feb	0600	1202.85
1980	4-Jan	2400	1197.64	29-Sep	0600	1205.05
1981	11-Sep	1800	1192.44	18-Feb	0600	1204.76
1982	5-Aug	2400	1196.25	31-Dec	2400	1208.37
1983	31-Jan	2400	1206.83	24-Jul	2200	1225.85
1984	4-May	2400	1205.73	23-Jul	1200	1213.73
1985	31-Dec	2400	1205.49	8-Jul	0600	1214.36
1986	24-Jan	2400	1201.42	2-Oct	2400	1213.20
1987	17-Jun	2400	1205.60	12-Feb	2400	1210.83
1988	29-Sep	2400	1199.14	28-Feb	2400	1211.82
1989	30-Nov	2400	1189.02	26-Feb	0600	1202.57
1990	24-Dec	1200	1177.87	5-Mar	0600	1191.88
1991	24-Sep	2400	1172.70	24-Feb	2400	1180.19
1992	21-Aug	2400	1173.39	24-Mar	2400	1180.55
1993	1-Jan	2400	1176.90	12-Apr	2400	1193.75
1994	30-Nov	2400	1175.67	27-Feb	2400	1190.98
1995	1-Jan	0100	1176.52	31-Dec	2000	1190.96
1996	14-Aug	2000	1189.68	15-Apr	1100	1195.05
1997	1-Jan	0200	1194.36	31-Dec	1000	1214.65
1998	29-May	2300	1211.37	15-Sep	1000	1215.95
1999	30-Jun	2100	1206.40	31-Dec	2000	1213.96
2000	13-Dec	2300	1195.67	10-Jan	1400	1214.14
2001	20-Dec	2100	1177.18	6-Feb	0900	1197.47
2002	31-Dec	1900	1152.10	28-Jan	0400	1178.04
2003	30-Dec	2300	1139.04	8-Mar	1700	1154.63
2004	31-Jul	2100	1125.69	25-Jan	1800	1140.58
2005	1-Jan	0001	1130.01	29-Mar	0700	1147.80
2006	3-Oct	2300	1125.14	27-Feb	0900	1141.39
2007	4-Oct	2300	1110.18	14-Feb	0500	1130.03
2008	31-Jul	2300	1104.41	11-Mar	0700	1117.96
2009	6-Nov	2300	1093.20	25-Jan	2100	1112.66
2010	27-Nov	2100	1081.85	26-Feb	0200	1103.35
2011	2-Jan	2100	1086.24	31-Dec	1800	1132.83
2012	21-Nov	0000	1114.96	22-Jan	1700	1134.56
2013	12-Nov	2200	1103.79	5-Feb	0400	1122.72
2014	13-Aug	2000	1080.19	2-Feb	0001	1106.96
2015	26-Jun	2300	1074.71	22-Jan	0800	1089.32
2016	1-Jul	2300	1071.61	18-Feb	0500	1084.46
2017	2-Aug	2200	1078.89	1-Mar	0200	1089.80
2018	11-Jul	2300	1076.38	12-Mar	1100	1088.35
2019	1-Jan	0000	1081.47	31-Dec	2300	1090.49
2020	26-Nov	2300	1081.04	30-Mar	1600	1096.71
2021	2-Dec	1700	1064.91	14-Feb	1400	1087.43

Data Source

1935 - 1937	Lake Mead and Colorado River Hydrographic Records
1938 - 1946	Watermaster Office Daily Log Records
1947 - 1986	D.W.P. Watermaster Office Daily Log Records
1987 - Present	Hoover Dam Control Room

Reference Elevations

Storage Capacity	1229.0 feet
Spillway Drum Gates	1221.4 feet
Bottom of Exclusive Flood Control Space	1219.6 feet
Crest - Spillway Top	1205.4 feet
Dead Storage	895.0 feet


Groundwater Recharge Suitability Map
Fresno
W Whites Bridge Ave
E Kings Canyon Rd
Sanger
Squaw Valley
S Hills Valley Rd
Orange Cove
Fowler
Parlier
Reedley
FRESNO
Selma
Caruthers
Dinuba
Orosi
Cutler
Kingsburg
Avenue 400
Riverdale
Laton
FRESNO
KINGS
Farmersville
SAGBI Rating Rating Class
85 - 100 Excellent
69 - 85 Good
49 - 69 Moderately Good
29 - 49 Moderately Poor
15 - 29 Poor
0 - 15 Very Poor
UC Davis SAGBI
The Soil Agricultural Groundwater Banking Index (SAGBI) is a suitability index for groundwater recharge on agricultural land. The SAGBI is based on five major factors that are critical to successful agricultural groundwater banking: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. More details can be found in the SAGBI article in California Agriculture.
Source: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels