GROUNDWATER USE ON SOUTHERN IDAHO DAIRIES

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ABSTRACT. *Dairy production has expanded in irrigated areas of the western and southwestern United States, potentially competing for limited water supplies. Groundwater withdrawal was measured for two years on six dairy farms with 660 to 6400 milk cows in southern Idaho. Groundwater withdrawal was calculated on an equivalent cow basis to account for relative differences in the numbers of milk cows, dry cows, heifers, and calves on each farm. Average groundwater withdrawal from each dairy varied from 110 to 250 L d^{-1} eq. cow^{-1} with an overall average of 190 L d^{-1} eq. cow^{-1} for the six farms. On an area basis, groundwater withdrawal varied from 180 to 880 mm y^{-1} on each farm with a mean of 530 mm y^{-1}. Estimated annual irrigation requirements in southern Idaho are 510 mm for spring barley, 590 for corn, and 920 for alfalfa. Wastewater that was available for irrigation was only measured on three farms and varied from 21 to 150 L d^{-1} eq. cow^{-1}, with the highest amounts from a freestall dairy. Assuming that wastewater replaced a portion of groundwater used for irrigation, the net groundwater used on these three dairies was 290 to 370 mm y^{-1}. Data from these six dairies indicated that groundwater withdrawal by dairy farms was similar or less than the amount of water required to meet evapotranspiration needs of irrigated crops in southern Idaho, especially if wastewater is used to offset irrigation and is not applied in addition to irrigation.*

Keywords. *Dairy farm, Groundwater withdrawal, Water use.*

Competition for water resources continues to increase in the western United States as an increasing population demands more water for food, energy, and recreation. Irrigation accounts for about 75% of the total freshwater withdrawal in the seven western states (Kenny et al., 2009). These seven states also have 38% of the milk cows in the United States. Idaho is now the third largest dairy state with the number of milk cows increasing 16% in the last five years and 54% in the last ten (USDA NASS, 2013). While livestock water use in Idaho is <1% of total freshwater use (Kenny et al., 2009), water rights associated with irrigated land have been transferred to dairy farms as milk production expanded in the irrigated areas.

A study of 16 dairies in California found that parlor water use varied from 170 to 734 L milk cow^{-1} day^{-1} (Meyer et al., 2006). Herd size varied from 125 to 2829 milk cows and parlor water use on an animal basis did not vary with size. A study of 11 dairies in Texas found that freshwater use for sanitation and manure removal varied from 46 to 262 L milk cow^{-1} day^{-1}, with herd size varying from 150 to 1300 milk cows (Sweeten and Wolfe, 1994). These two studies did not include cow drinking water because the primary objective was determining the amount of wastewater that needed to be stored. Milk cows can consume 2 to 2.7 L kg^{-1} milk produced per animal per day (NRC, 2001) or about 80 L cow^{-1} day^{-1} (Meyer et al., 2004; Cardot et al., 2008). Brouk et al. (2002) measured drinking water on three freestall dairies in Kansas during one summer. Drinking water use varied from 106 to 171 L cow^{-1} day^{-1}, or 2.6 to 5.4 kg water per kg of milk produced. Average milk production varied from 26 to 45 kg cow^{-1} day^{-1}. Brugger and Dorsey (2008) measured water use on a 1000 milk cow dairy in Ohio and found that average monthly drinking water use varied from 44 to 128 L cow^{-1} day^{-1} (included milking and dry cows), with the lowest values in the winter and highest in the summer. They also measured water usage for cleaning the parlor and milking equipment, which varied from 21 to 29 L cow^{-1} day^{-1} with no seasonal variation. Milk production averaged 36 kg cow^{-1} day^{-1} during the two year study.

Estimates of dairy water use are needed to ensure that sufficient water is transferred for new dairies and to determine potential impacts on other water users. The objective of this study was to determine the total groundwater withdrawal by modern dairies in southern Idaho in comparison to water use by irrigated crops. A secondary objective was to estimate net groundwater use by dairies assuming that wastewater was used to directly replace irrigation water for crop production.

MATERIALS AND METHODS

Six cooperating dairy farms were identified in 2009 (table 1). These farms represented typical types and sizes of dairies in southern Idaho and the western United States. All

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dairies had Holstein milk cows with the exception of dairy 3, which had Jersey milk cows for 30% of its herd. The number of milk cows on each farm varied <10% throughout the study. Dairies 1 and 3 had milk cows in both freestall barns and open lots, with about 60% of the milk cows in open lots. All milk cows at dairy 5 were housed in two freestall barns, but cows had access to exercise pens adjacent to the barns. Manure was vacuumed from all freestall barns, not flushed with water. Gravity and mechanical separation were used to remove solids from vacuumed manure before it entered the wastewater storage ponds. All open lots had shade for cows and freestall barns had fans for cooling. Dairies 1, 3, and 5 had holding pen or parlor deck flush systems that automatically flushed after each group of cows. Chiller plate water was reused for cow drinking water and parlor wash water on all dairies except dairy 6, which only reused chiller plate water for drinking water. All dairies with calves on site used water for milk replacer and bottle washing.

Groundwater withdrawal was measured from December 2009 to November 2011 on each dairy with water meters installed on all wells. Dairies 1-5 had electromagnetic flow meters on all wells. Dairy 6 had a mechanical flow meter. Cumulative flow volume was manually recorded every two to four weeks. New meters had to be installed on dairy 4 so data collection started about 4 months later than the other sites. Well flow meters were checked at least once with an ultrasonic flow meter to verify that meters were operating properly.

Wastewater produced on these dairies was stored in ponds until it could be applied to cropland through sprinkler irrigation. Dairy 2 applied all wastewater during 2-week periods in the spring and fall. All other dairies applied wastewater throughout the growing season. The amount of wastewater applied to cropland was measured on dairy 2 with an ultrasonic flow meter with clamp-on transducers attached to the wastewater irrigation pipe. The meter recorded cumulative flow volume during each application period. Diaries 4 and 5 pumped wastewater from a sump into a storage pond. Pump operating time was recorded with a data logger and multiplied by the calibrated flow rate for the pump. The calibrated pumping rate was periodically calculated by measuring the volume change with time in the wastewater sump during a pump cycle. It was not practical to measure wastewater on dairy 1 because wastewater was pumped from three ponds to multiple fields with multiple pumps, which also periodically transferred wastewater between two ponds. Wastewater flowed into the ponds through underground pipes with typically submerged outlets. The pond inlet pipe was also submerged on dairy 3 and it was not possible to measure flow from the floating wastewater pump during the study period. Dairy 6 produced very little wastewater and it was not practical to measure flow into or out of the small storage pond.

The surface area covered by each dairy was determined from aerial images, as well as irrigated lawn and wastewater pond areas. Evaporation from wastewater ponds on dairies 4 and 5 was calculated to estimate the amount of wastewater remaining that could be used for irrigation. Pond evaporation was estimated at 1100 mm y^{-1} using a crop coefficient of 0.7 and average reference evapotranspiration (ET) of 4.3 mm d^{-1} as recommended by Allen and Robison (2012) for shallow ponds (<4 m). Net annual pond evaporation was calculated as 840 mm by subtracting average annual precipitation of 260 mm (USBR, 2013) from estimated pond evaporation. Potential water use by alfalfa, corn, and spring small grain were obtained from AgriMet (USBR, 2013), the US Bureau of Reclamation's Pacific Northwest cooperative agricultural weather network. Net irrigation requirements for these crops were obtained from ET Idaho (Allen and Robison, 2012).

Groundwater withdrawal on an area basis was calculated by dividing the water volume by the total area covered by the dairy, including feed, bedding and waste storage areas. Water use data were also presented on an animal basis. Dairies are often characterized by the number of milk cows so water use was presented per milk cow. Since these dairies had different relative amounts of milk cows, dry cows, heifers and calves, the number of equivalent milk cows was calculated for each dairy. An equivalent milk cow was defined as 1 milk cow, 0.45 dry cow, 0.3 heifer, or 0.1 calf based on typical fresh water consumption for dairy animals (Linn et al., 2008). Animals were categorized as

Table 1. Average number of animals and water use characteristics on the six monitored dairies.

	Dairy					
	1	2	3	4	5	6
Type	Open lot a freestall	Open lot	Open lot & freestall	Open lot	Freestall	Open lot
Milk cows	6430	710	1550	1970	5550	660
Dry cows	690	100	220	270	740	170
Heifers[a]	240	270	190	420	720	280
Calves[b]	1580	-	250	230	-	-
Total equivalent milk cows[c]	6970	830	1730	2240	6100	830
Wells	6	2	2	2	2	1
Parlors	3	1	1	1	1	1
Vacuum pump cooling	Air	Air	Air	Air	Air	Air
Compressor cooling	Air	Air	Water	Water	Air	No
Holding pen flush	Yes[d]	No	Yes	No	Yes	No
Parlor deck spray/flush	Yes[d]	No	Yes	No	Yes	No
Reuse chiller plate water	Yes[d]	Yes	Yes	Yes	Yes	Yes

[a] Includes heifers and springers.
[b] Includes animals up to 200 kg.
[c] Based on average water intake from Linn et al. (2008). Milk cow = 1.0, Dry cow = 0.45, Heifer = 0.3, and Calf = 0.1.
[d] Dairy 1 had three parlors: two parlors had holding pen flush, three parlors had deck spray/flush and reuse chiller plate water.

calves from birth to 200 kg and as heifers from 200 kg until they began milking.

RESULTS AND DISCUSSION

Total groundwater withdrawal for the six dairies varied from 85 to 360 L d^{-1} eq. cow^{-1} during the study (fig. 1). An increase in groundwater withdrawal was evident during the summer on all dairies. The summertime increase corresponded to the increase in average daily air temperature (fig. 1). The increase in groundwater withdrawal during summer was approximately 100 L d^{-1} eq. cow^{-1} on dairies 2, 3 and 4. Groundwater withdrawal was more erratic on dairy 3 than the other dairies. The operator noted that a leaking water tank was fixed in May 2010, which was probably the reason for the spike in groundwater withdrawal in May. Dairy 3 also underwent management change during this study, which may have caused inconsistent operation at the dairy. Water use was not measured within the dairies so the specific causes of increased groundwater withdrawal could not be identified. Increased water consumption by animals likely accounted for part of the increase. Studies have shown that water consumption for dairy cows can increase 29% when air temperature increased from 18°C to 30°C and 25% when minimum daily temperature increased from 0°C to 25°C (NRC, 2001). Brugger and Dorsey (2008) reported a 56 L d^{-1} cow^{-1} difference in average monthly drinking water use between summer and winter on an Ohio dairy. The large increase in groundwater withdrawal on dairies 2, 3, and 4 must have resulted from water uses other than increased water consumption by cows, but none of these dairies used water for sprinklers or misters to cool the cows or suppress dust. Seasonal trends were less pronounced on dairies 1, 5, and 6, varying 50 to 60 L d^{-1} eq. cow^{-1} between summer and winter, which could be accounted for by changes in water consumption by cows.

Groundwater withdrawal on an area basis varied from 0.3 to 3 mm d^{-1} (fig. 2). Dairies 3 and 5 had the greatest groundwater withdrawal per hectare because the number of milk cows per hectare was greatest on these two dairies (table 2). Total annual groundwater withdrawal was 800 and 880 mm y^{-1} for dairies 3 and 5, respectively (table 2). Dairy 6 only used 180 mm y^{-1} because of the low cow density (37 milk cow ha^{-1}) and the operator used very little wash water in the parlor. Mean potential ET for the last twenty years was 990 mm for alfalfa, 630 mm for corn, and 590 mm for spring small grain in southern Idaho (USBR, 2013). Estimated precipitation deficits, or net annual irrigation requirements, were 920 mm for alfalfa, 590 mm for corn and 510 for spring small grain (Allen and Robison, 2012). Overall, groundwater withdrawals on an area basis for the dairies in this study were similar or less than estimated irrigation requirements for typical crops in the area. Groundwater withdrawals for dairies 3 and 5 were 13% and 4% less than estimated irrigation requirements for alfalfa; dairies 1 and 4 were similar to irrigation requirements for spring grain.

Average groundwater withdrawal for each dairy during the study period varied from 110 to 250 L d^{-1} eq. cow^{-1} (table 2). The mean for the six dairies was 190 L d^{-1} eq. cow^{-1}. Dairies 2-5 each had a small amount of lawn that

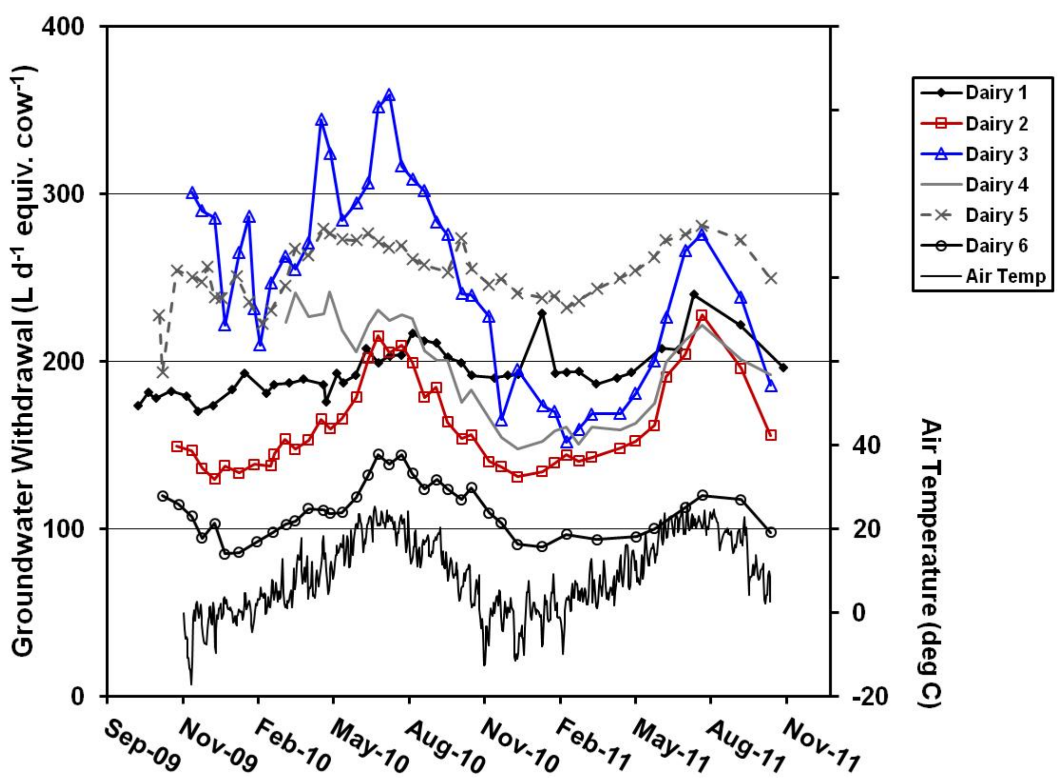

Figure 1. Groundwater withdrawal on an animal basis for six dairy farms in southern Idaho and average daily temperature from Kimberly, Idaho.

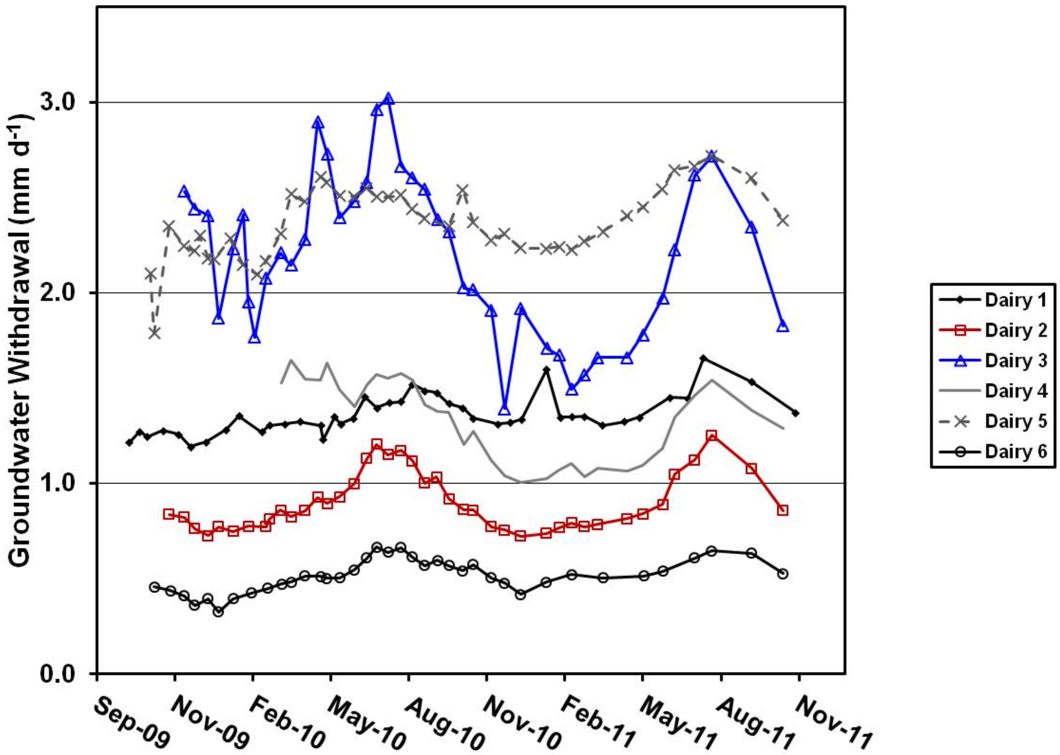

Figure 2. Groundwater withdrawal on an area basis for the six dairy farms.

was irrigated from the dairy supply wells. Assuming these areas were irrigated to meet potential ET, lawn irrigation varied from 0.3 to 4% of the total groundwater withdrawal on the dairies and was less than 7 L d^{-1} eq. cow^{-1}. Water consumed with feed was not measured as part of this study. A typical milk cow ration in this area is about 60% dry matter with approximately 15 kg d^{-1} dry matter consumption, which would provide 10 L of water per day for every milk cow. Milk production was 32 L d^{-1} milk cow^{-1}.

Wastewater measurements were only available for dairies 2, 4, and 5. Wastewater used for irrigation was directly measured on dairy 2 and equaled 21 L d^{-1} eq. cow^{-1} (table 2), which was equivalent to 13% of the groundwater withdrawal on the dairy. On dairies 4 and 5, wastewater was measured as it was pumped into storage ponds and equaled 83 and 190 L d^{-1} eq. cow^{-1}, respectively. Dairy 5 was a freestall dairy so the measured wastewater contained all urine and feces collected from the barns after gravity and mechanical separation to remove solids. Manure was collected with vacuum trucks, not flushed from the barns, so no additional water was added during manure removal. Assuming pond evaporation was 840 mm y^{-1} (Allen and Robison, 2012), 70 and 150 L d^{-1} eq. cow^{-1} of wastewater would be available to irrigate fields from dairies 4 and 5, respectively (table 2). This wastewater volume was equal to 34% and 53% of the total groundwater withdrawal for dairies 4 and 5.

If wastewater was used to offset groundwater for irrigation, net groundwater use on dairies 2, 4, and 5 varied from 100 to 139 L d^{-1} eq. cow^{-1} (table 2) with an average of 120 L d^{-1} eq. cow^{-1}. The net groundwater use on an area basis varied from 290 to 370 mm y^{-1} and averaged

Table 2. Water use on six monitored dairies.

	Dairy						
	1	2	3	4	5	6	Average
Dairy area (ha)	100	15	19	33	65	17	42
Milk cows/ha	64	47	81	60	85	37	62
Milk production (L/milk cow/d)	36	32	32	32	30	31	32
Groundwater Withdrawal							
Area basis (mm/y)	510	330	800	470	880	180	530
Animal basis (L/eq. cow/d)[a]	190	160	250	200	250	110	190
(L/milk cow/d)	210	190	270	220	280	140	220
Wastewater volume							
Produced (L/eq.cow/d)	-	-	-	83	190	-	130
Applied (L/eq. cow/d)	-	21	-	70	150	-	80
Net water use							
Area basis (mm/y)	-	290	-	310	370	-	320
Animal basis (L/eq. cow/d)	-	139	-	130	100	-	120
(L/milk cow/d)	-	165	-	140	120	-	140

[a] Eq. cow is equivalent milk cow based on milk cow = 1.0, dry cow = 0.45, heifer = 0.3, and calf = 0.1.

320 mm y^{-1} for the three dairies with measured wastewater volumes. The average net water use was 35% of the estimated irrigation requirement for alfalfa, 54% of corn, and 63% of spring small grain. Again, this assumes that wastewater replaced irrigation water used for crops and was not applied in addition to irrigation water required for crop ET. Also, many areas in southern Idaho are irrigated with surface water so dairy wastewater would not replace any groundwater use in these areas.

The mean groundwater withdrawal of 190 L d^{-1} eq. cow^{-1} or 220 L d^{-1} milk cow^{-1} for the six dairies in this study was less than the 290 L d^{-1} milk cow^{-1} measured on 16 dairies in California, which did not include cow drinking water (Meyer et al., 2006). An earlier study of 11 dairies in Texas found that average freshwater use for sanitation and manure removal was 150 L d^{-1} milk cow^{-1} (Sweeten and Wolfe, 1994). Assuming water consumption by cows is about 80 L d^{-1} milk cow^{-1}, total water consumption on the 11 Texas dairies would have ranged from about 130 to 340 L d^{-1} milk cow^{-1}, which is similar to the current study.

CONCLUSIONS

Groundwater withdrawals were measured for two years on six dairies in southern Idaho. Average groundwater withdrawal for each dairy varied from 110 to 250 L d^{-1} eq. cow^{-1} or 140 to 280 L d^{-1} milk cow^{-1}, with an overall average of 190 L d^{-1} eq. cow^{-1} or 220 L d^{-1} milk cow^{-1}. Annual groundwater withdrawal on an area basis varied from 180 to 880 mm for the six dairies and averaged 530 mm. These values were similar or less than the estimated irrigation requirements for typical crops grown in the area. Wastewater produced was measured on three of the six dairies. Assuming wastewater offset irrigation water, net groundwater use varied from 290 to 370 mm y^{-1} (320 mm y^{-1} average) or 100 to 139 L d^{-1} eq. cow^{-1} (120 L d^{-1} eq. cow^{-1} average). The average net water use was 35% of the estimated irrigation requirement for alfalfa, 54% of corn, and 63% of spring small grain in southern Idaho. This study demonstrated that groundwater used by southern Idaho dairies was similar or less than water used for irrigated crops.

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