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Technical Note: Stream temperatures as related to subsurface waterflows originating from irrigation

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Abstract

Continuous stream temperature data were collected from adjacent reaches of a third-order stream in eastern Oregon. The upstream reach was located within a non-irrigated meadow and the downstream reach was located within an irrigated meadow. Sensors were placed in the stream above a head-ditch irrigation diversion, in the irrigation ditch, in the subsurface (interflow) groundwater, and in the stream reach within the irrigated meadow. Daily maximum stream temperature in the reach located within the irrigated meadow was found to be 1 to 3°C cooler than the non-irrigated reach. Daily minimum stream temperatures exhibited the opposite relationship with the reach within the irrigated meadow ranging from 0.5 to 1.7°C warmer than the non-irrigated meadow reach.

Key Words: stream temperature, groundwater, subterranean return flow

There is growing concern that agricultural irrigation practices which divert stream water have a negative impact on water quality by decreasing stream flow and increasing water temperature. Although there are a number of interrelated factors that determine the thermal characteristics of streams the most important hydrologic variables have been identified as the source of the water, the flow or discharge, and the relative contribution of groundwater (Ward 1985). Stream segments that receive a proportionately greater contribution of groundwater at low flow exhibit depressed daily maximum temperatures (Mosley 1983; McRae and Edwards 1994). Subterranean irrigation, where water is diverted from the stream, carried by a ditch along the flood plain edge and allowed to return to the stream via subsurface interflow, may mimic the cooling effect noted with groundwater discharge. We implemented a case study to test the hypothesis that cooler, relatively temperature-stable subsurface water flows, originating from irrigation, moderate stream temperatures.

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Resumen

Datos continuos de la temperatura de la corriente fueron colectados en canales adyacentes irrigados y sin irrigar en una corriente de tercer orden en el este de Oregón. Los sensores fueron colocados en la corriente arriba del desviador de riego del canal de acceso, en el canal de irrigación, en el agua del subsuelo (flujo interno), y en el canal dentro de la pradera irrigada. Se encontró que la temperatura máxima diaria de la corriente en el canal localizado dentro de la pradera irrigada fue de 1 a 3°C mas fría que en los canales sin irrigación.

Site Description

The study site was located on a third-order stream in south central Grant County, Oregon. Grant County is situated in the Central Blue Mountains of east-central Oregon and lies between 44° and 45° north latitude and 118° and 120° west longitude. The study stream drains a watershed of approximately 1,950 km^2. Two adjacent stream segments, 1 located upstream of an irrigation diversion and 1 located within the irrigated meadow were chosen for the study. Both segments occur in a common meadow that ranges in elevation from 1,450 to 1,500 m. The meadow associated with the non-irrigated stream segment was approximately 155 m in width and received some topographic shading. Meadow width at the top of the irrigated portion of the meadow was approximately 308 m, widening to 615 m, 500 m downstream. There was no topographic shading within the irrigated meadow. Willow frequency along the non-irrigated reach exceeded the irrigated segment by 1.5 times. The irrigated and non-irrigated stream segments had similar width to depth ratios (2.12 vs 2.10), sinuosity and gradients (less than 2%). Streambed material is hard cobble with a gravel overlay, lacking in permeability. The floodplain soil is classified at the series level as Damon silty clay loam. It is poorly drained, formed in mixed alluvium with a restrictive layer at 100 to 130 cm. Average summer air temperature is 13.8°C with maximum temperatures occurring in July and August. Mean annual precipitation is 330 mm with the majority of it coming in the form of snow (Oregon Climate Service 1996).

Table 1. Stream discharge in cubic meters per second.

Date	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
			(m^3/sdc)				
15/Jun/95	1.68	.88	1.38	1.25	1.04	.07	.09
29/Jun/95	1.0	.61	.99	.80	.78	.06	.08
6/Jul/95	.68	.53	.85	.65	.60	—	—
22/Jul/95	.27	.26	.46	.41	.35	—	—
9/Aug/95	.39	.17	.30	.30	.26	—	—
22/Aug/95	.30	.12	.24	.20	.18	—	—

Site 1 = discharge station within non-irrigated meadow.
Site 2 = discharge station 20 m downstream of diversion dam.
Site 3 = discharge station within irrigated meadow.
Site 4 = discharge station within irrigated meadow.
Site 5 = discharge station within irrigated meadow.
Site 6 = discharge station within irrigation ditch.
Site 7 = discharge station within irrigation ditch.

Methods and Materials

Five permanent discharge stations were established on the stream in May 1995. Three within the irrigated meadow, 1 directly downstream from the irrigation diversion dam and one, 1,314 m upstream from the dam. In addition, 2 permanent irrigation discharge stations were located in the head ditch. At each station stream/ditch cross-section profiles and discharge measurements were completed every 2 weeks from June through September. Channel profiles were constructed through measurement of stream width and channel depth with depth recorded every 30 cm. Discharge measurements were recorded every 2 weeks from June through September using a pygmy style flow meter.

Wells for measuring depth to water table were placed along transect lines perpendicular to the flow of the stream. Three transects with 4 wells each were placed on the north side of the creek within the irrigated meadow. The first well in each transect was located immediately adjacent to the creek, the second a minimum of 15 meters from the first, the third 2 to 5 meters downslope of the head ditch and the last well 2 to 5 meters upslope of the ditch. Water table depth was measured every 10 days during the irrigation season and every 3 days from the end of the irrigation season until baseflow level was reached.

Thermistors, programmed to record temperature every 36 minutes, were placed within completely mixed sections of the creek and the irrigation ditch at each discharge station. Four wells located on the downslope side of the ditch were randomly chosen as groundwater (interflow) temperature sites. A thermistor programmed to record temperature every 3 hours was placed 70 cm below the ground surface next to each of the 4 wells. Additional thermistors recorded air temperature in shaded areas at both the non-irrigated site and at 2 sites within the irrigated meadow.

Stream temperature data were subdivided into 2 groups as determined by the end of the spring runoff period. The temperature data recorded during the spring runoff period was assigned to the "early" group and temperature data recorded after runoff ended was designated to the "late" group. The difference between daily maximum stream temperatures for the non-irrigated and irrigated stream segments were tested within groups using a paired t-test. The same procedure was repeated for the daily minimum stream temperatures. In addition, the difference in daily maximum and daily minimum air temperature between the non-irrigated and irrigated segments were tested using a paired t-test.

Results and Discussion

The diversion of stream water for irrigation began in March, ended in late July and resumed in September. Mid-June flow measurements indicated a 0.8 m^3/s (29 cfs) reduction in flow directly below the dam from 1.7 m^3/s (60.0 cfs) to 0.9 m^3/s (31.1 cfs) (Table 1). However, 486 meters downstream of the dam flow was 1.4 m^3/s (48.6 cfs) indicating a substantial return flow from irrigation. A large decrease in stream flow occurred between early and late July. Flow decreased on average 0.34 m^3/s (12 cfs) marking the end of the spring runoff period.

Following irrigation shut-off the water table in the creekside wells dropped an average of 24 cm from July 5 through July 23. Water table drop in the wells closest to the ditch averaged 61 cm. The immediate change in depth to water table associated

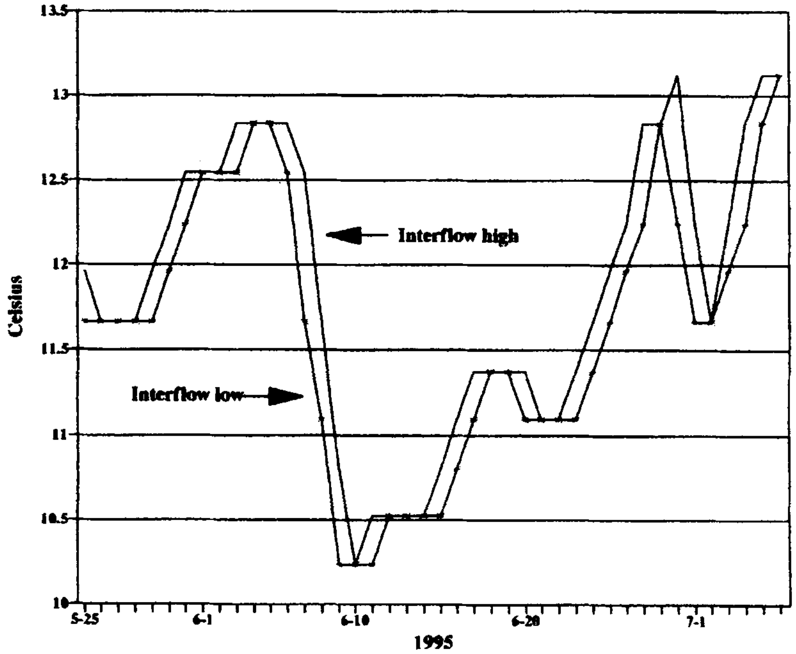

Fig. 1. Daily maximum and minimum interflow (groundwater) temperatures within the irrigated meadow.

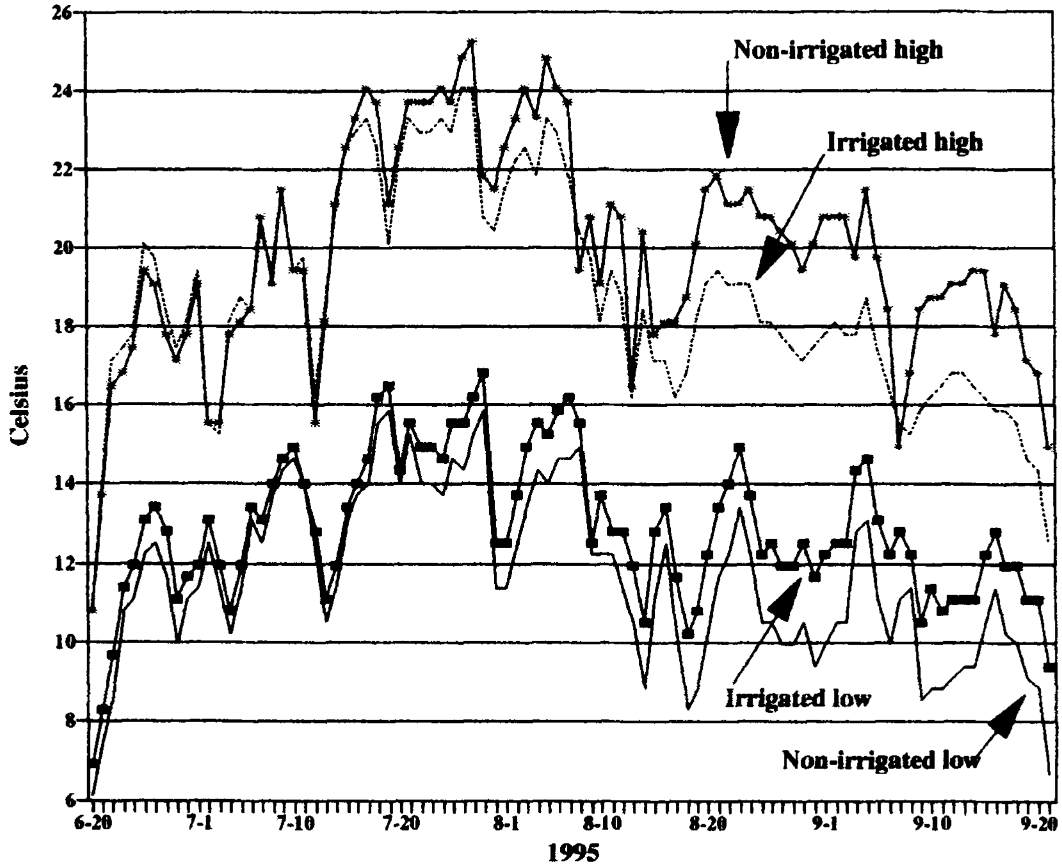

Fig. 2. Daily maximum and minimum water temperatures in stream reaches contained within adjacent non-irrigated and irrigated meadows.

with irrigation cessation demonstrated the impact of irrigation on interflow.

Subsurface water temperature fluctuated less than 3°C from June through August and ranged from 10 to 13°C. The spread between daily high and low averaged close to 0.5°C (Fig. 1). The average high air temperature for the non-irrigated site was 22.5°C and the maximum daily high of 31°C occurred on July 28. The average high air temperature for the irrigated meadow sites was 22.7°C and the maximum daily high of 32°C occurred on 1 September. No significant difference in daily high air temperatures was found between the irrigated and non-irrigated meadow sites ($t = .-0.87$, $df = 116$, $P = 0.39$). Ditch water daily high temperature ranged between 7.5 and 20°C with a high temperature average of 14.6°C. Stream water temperature at the non-irrigated and irrigated sites followed a similar pattern until mid-July when a divergence appeared (Fig. 2). This divergence appears to be related to the end of the spring runoff period. Daily maximum stream temperatures were 1 to 3°C cooler in the irrigated reach than in the non-irrigated meadow reach from mid-July through September ($t = -15.7$, $df = 59$, $P < 0.0001$). Daily low stream temperatures exhibited the opposite relationship with the irrigated reach ranging from 0.5 to 1.7°C warmer than the non-irrigated reach ($t = 24.1$, $df = 59$, $P < 0.0001$). No differences in daily maximum stream temperatures were found in the May through mid-July data ($t = 1.73$, $df = 56$, $P = 0.09$). However, the daily minimum stream temperature for the irrigated reach was significantly warmer than the daily minimum temperature for the stream reach located within the non-irrigated meadow ($t = 20.45$, $df = 59$, $P < 0.0001$).

Our results suggested that downstream temperatures were moderated by relatively temperature-constant, subsurface return flows generated by subterranean irrigation. However, further study of ground water within the non-irrigated reach is warranted. Replication of the study across time and space is necessary to confirm this apparent conclusion.

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