Lateral ground-water velocities in the eastern part of the area, computed during model simulations, range from less than 1.0 ft/yr to more than 30 ft/yr in the basal Williams Fork aquifer and from less than 0.1 ft/yr to more than 3.0 ft/yr in the Twentymile aquifer. The distribution of lateral velocities shown in figures 38 and 39 indicate that larger velocities generally are located near the margins of the aquifer and smaller velocities are prevalent in the central parts of the aquifers. The combined effects of relatively large hydraulic conductivity and potentiometric gradient result in a larger ground-water velocity along the fault area near the eastern margin of the aquifers. Other faults or interconnected fracture systems could have similar but less pronounced effects on local ground-water velocities. Lack of data prevents individual simulation of any such local features. However, the larger scale effects of local faults and fractures are incorporated in the model through use of spatially distributed hydraulic conductivity, which is based in part on results of aquifer tests in potentially fractured aquifers. Although ground-water velocities cannot be precisely determined because of this lack of data and associated uncertainties in the model parameter values, the magnitude of velocities shown in figures 38 and 39 are significant in that very slow rates of ground-water flow are indicated. A contaminant that enters the bedrock aquifer will not move rapidly to other parts of the area and could remain virtually immobile at some locations.

WATER BUDGET

The ground-water flow model was used to estimate the steady-state water budget for the eastern part of the study area. The simulated water budget (table 9) indicates that total recharge for, or discharge from, the bedrock aquifers is only about 2.6 ft^3/s. This small rate if flow us consistent withe small hydraulic conductivity and small well yields observed formations that are classified as marginal aquifers in this study. Recharge and discharge for each aquifer by major surface drainage area is listed in table 9. For example, the model calculated that the Twentymile aquifer receives 0.0946 ft^3/s of precipitation recharge from that part of the Sage Creek Drainage area that overlies the aquifer; the aquifer loses 0.0777 ft^3/s of discharge to evapotranspiration in the same area. Recharge may come from percolation of water in streams and ponds or from deep infiltration of precipitation. Discharge may be evapotranspiration or to streamflow and alluvial aquifer. Estimated total recharge to the basal Williams Fork aquifer is about 1.4 ft^3/s to the Twentymile aquifer is similar, but recharge is only about 0.02 ft^3/s in the Trout Creek aquifer. Recharge and discharge to the Trout Creek aquifer is limited by the small transmissivity and very limited outcrop area of the aquifer. Vertical leakage (the difference between total inflow and total outflow through the lateral boundaries of the aquifer) is the rate of flow through the confining layers that separate each aquifer. The Trout Creek aquifer receives about 5 percent of its recharge as leakage for the overlying basal Williams Fork aquifer and discharges about 90 percent of inflow into the basal Williams Fork aquifer in other areas.

The accuracy of the simulated water budget is affected by the size of the grid interval used in modeling, by the accuracy of the model parameters, and by the extent of the model calibration. The 2,000-ft grid interval used in this model provides a resolution of 930 nodes in the Trout creek aquifer, 920 nodes in the basal Williams fork aquifer, 530 nodes in the Twentymile

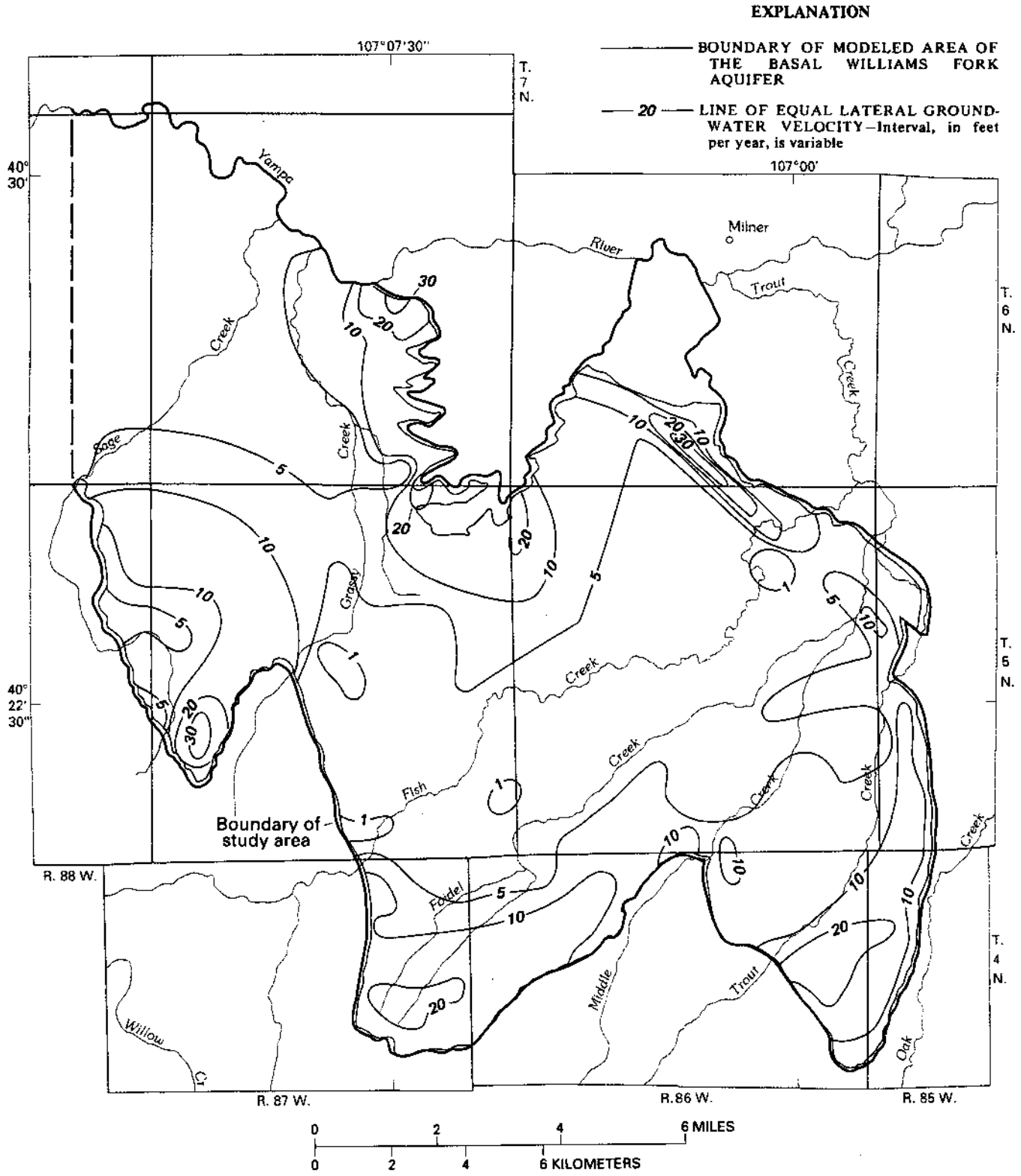

Figure 38.--Magnitude of lateral ground-water velocities in the basal Williams Fork aquifer in the eastern part of the study area.

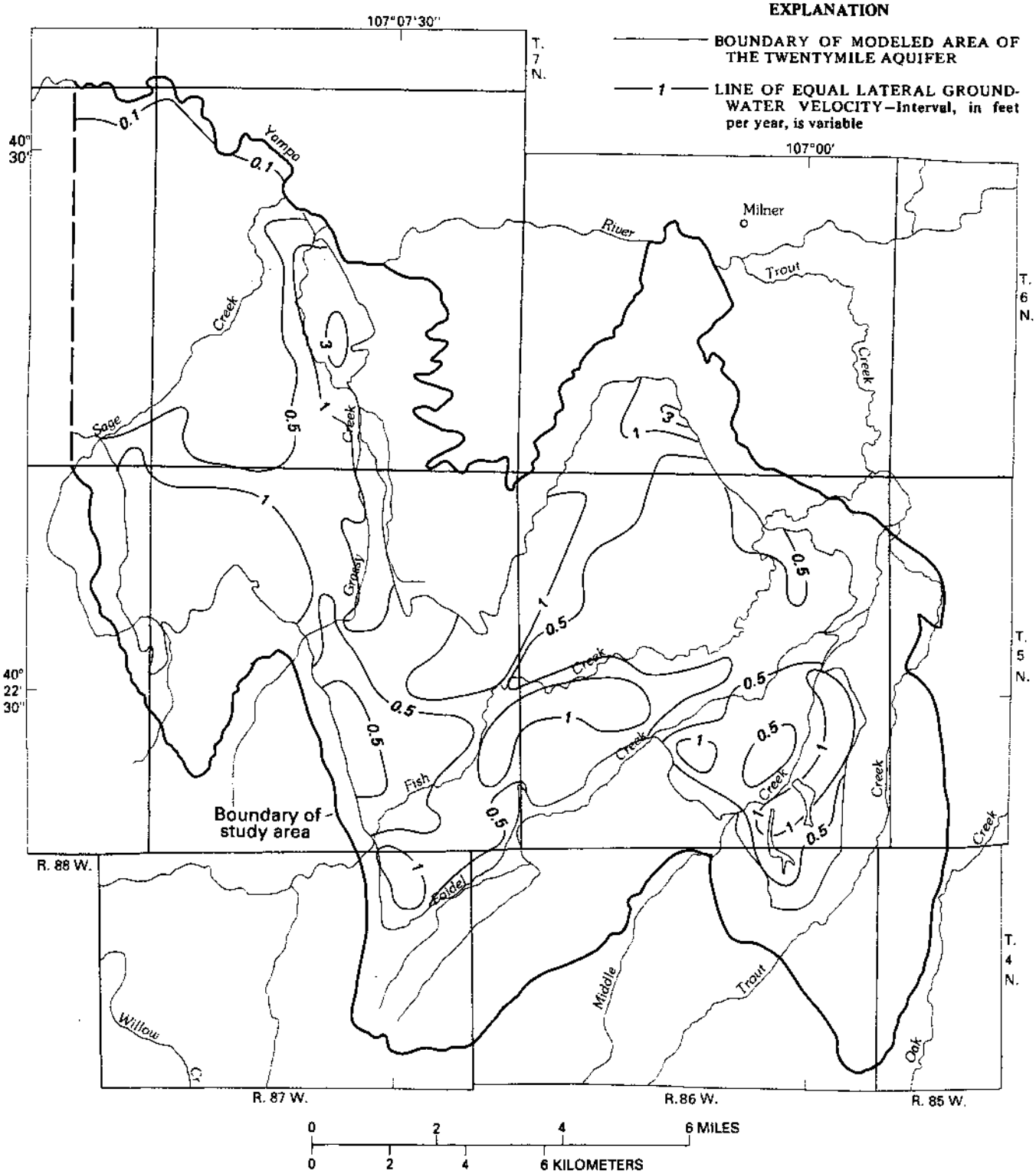

Figure 39.--Magnitude of lateral ground-water velocities in the Twentymile aquifer in the eastern part of the study area.

Table 9.--*Simulated steady-state water budget for aquifers in the eastern part of the study area*

[ft^3/s, cubic feet per second]

Component	Layer[1]	Flow rate (ft^3/s) in specified drainage area[2]						
		Sage Creek	Grassy Creek	Fish Creek	Foidel Creek	Middle Creek	Trout Creek	Total
				Ground-water recharge				
Precipitation	1	0.0946	0.6209	0.3389	0.1101	0.1366	0.0103	1.3114
	2	0.1869	0.4534	0.1506	0.2934	0.1393	0.2249	1.4485
	3	0.0016	0.0145	0.0040	0.0007	0.0015	0.0012	0.0235
Subtotal		0.2831	1.0888	0.4935	0.4042	0.2774	0.2364	2.7834
Streamflow	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0.0023	0.0023
	3	0	0	0	0	0	0.0002	0.0002
Subtotal		0	0	0	0	0	0.0025	0.0025
Total recharge		0.2831	1.0888	0.4935	0.4042	0.2774	0.2389	2.7859
				Ground-water discharge				
Streamflow	1	0.1144	0.4020	0.1690	0.0553	0.0804	0	0.8211
	2	0.1938	0.0908	0.0863	0.1640	0.1030	0.2112	0.8491
	3	0.0011	0.0025	0.0005	0.0004	0.0031	0.0012	0.0088
Subtotal		0.3093	0.4953	0.2558	0.2197	0.1865	0.2124	1.6790
Evapotrans-piration	1	0.0777	0.2634	0.2894	0.0072	0	0	0.6377
	2	0	0.2021	0.0278	0.2368	0.0024	0	0.4691
	3	0	0	0	0	0	0	0
Subtotal		0.0777	0.4655	0.3172	0.2440	0.0024	0	1.1068
Total discharge		0.3870	0.9608	0.5730	0.4637	0.1889	0.2124	2.7858
				Vertical leakage				
Downward movement of water through confining unit underlying model layer	1	0.0352	0.2796	0.1764	0.0620	0.0900	0.0105	0.6537
	2	0.0055	0.0187	0.0118	0.0155	0.0066	0.0108	0.0689
	3	0	0	0	0	0	0	0
Subtotal		0.0407	0.2983	0.1882	0.0775	0.0966	0.0213	0.7226
Upward movement of water through confining unit underlying model layer	1	0.1359	0.3262	0.2850	0.0264	0.0277	0	0.8012
	2	0.0100	0.0228	0.0204	0.0183	0.0024	0.0098	0.0837
	3	0	0	0	0	0	0	0
Subtotal		0.1459	0.3490	0.3054	0.0447	0.0301	0.0098	0.8849

[1]Layer 1, Twentymile aquifer; layer 2, basal Williams Fork aquifer; layer 3, Trout Creek aquifer.
[2]See figure 22 for location of drainage areas.

aquifer. This large number of nodes provides sufficiently detailed resolution for the purposes of this investigation. The model parameters range in accuracy from the well-defined data on aquifer extent, thickness, and outcrops, to relatively poorly defined data on hydraulic conductivity and recharge and discharge. These data adequately define the hydrologic conditions in the model area, and a good model calibration was achieved.

The model was calibrated by comparing the model-calculated potentiometric surface maps with measured potentiometric surface maps and by comparing model-calculated discharge with measured changes in streamflow. The close agreement between the calculated and measured potentiometric surfaces for each aquifer indicates that the model is a good simulator of the steady-state flow system in the aquifers. The water budget calculated by the model also should be a good estimate of the actual water budget for the area and likely is of better accuracy than water-budget information based on field measurements.

It generally is difficult or impossible to make direct field measurements of most components of a water budget. In many instances, the component to be measured is spatially or temporally variable or is inaccessible for measurement. Gain or loss in streamflow may occur in response to ground-water discharging into, or recharging from, a stream. The long-term average gain or loss in streamflow is difficult to measure because of the short-term effects of storm runoff, interaction with flow in alluvial aquifers, evapotranspiration from phreatophytes, and diversions. Gain or loss in streamflow was measured along 71 reaches of selected streams in July, August, and September 1986 (table 3). Pertinent gain-loss data are summarized in table 10 for purposes of comparison with surface-water gain-or-loss data calculated by the steady-state model. The difficulty in relating instantaneous measurements of streamflow to long-term average streamflow are apparent. However, the measured and model-calculated values of gain or loss are of comparable magnitude, which indicates that the model-calculated water budget likely is a reasonable estimate of the actual steady-state water budget.

GROUND-WATER GEOCHEMISTRY

The chemical composition of ground water is the result of geochemical processes that include dissolution of soluble minerals from the soil and aquifer matrix, chemical reactions and ion exchange reactions between dissolved constituents, and precipitation of minerals. The large number of dissolved constituents in water, and the complex geochemical processes that may affect the concentrations of these constituents, make identification of most geochemical reactions difficult even when adequate data are available. In the western part of the study area, ground-water-quality data are few and poorly associated with individual aquifers. In the eastern part of the area, the more numerous chemical analyses associated with specific aquifers enable evaluation of some geochemical processes. The prevalence of these geochemical processes in nature and the similarity of geology, hydrology, climate, and topography, between the eastern and western parts of the study area indicate that geochemical processes identified in the eastern part of the area also likely are occurring the western part of the area, even though data may be lacking.