Supplementary Information

1   Developing the mesh

Two major considerations governed the 2D model discretization; 1) the stream network extent represented in the mesh; and 2) the mesh refinement along the stream network. A representative stream network was needed to be able to capture the development of active areas leading to streamflow generation in different parts of the catchment, while smaller elements along the streams were needed to better capture the topographic features allowing a more accurate representation of the hydrodynamic processes.

Several meshes were tested for suitability (Figure SI1). Initially, we created a 2D mesh which consisted of 57,978 nodes and 115,168 triangular elements with a ≈5-10 m nodal spacing around the streams in comparison to the ≈0.5-3 m stream width observed in the field. The coarser resolution along the stream sections was a compromise to include a larger stream network which would be representative of the three major areas in the catchment. A preliminary model test showed that the model convergence was extremely slow, and the 2D surface discretization was relaxed. The final 2D surface domain discretisation consisted of 3015 nodes and 5869 triangles. We then tested four different scenarios by incising the stream nodes by 4, 6, 8 and 10 m respectively (Figure SI1).
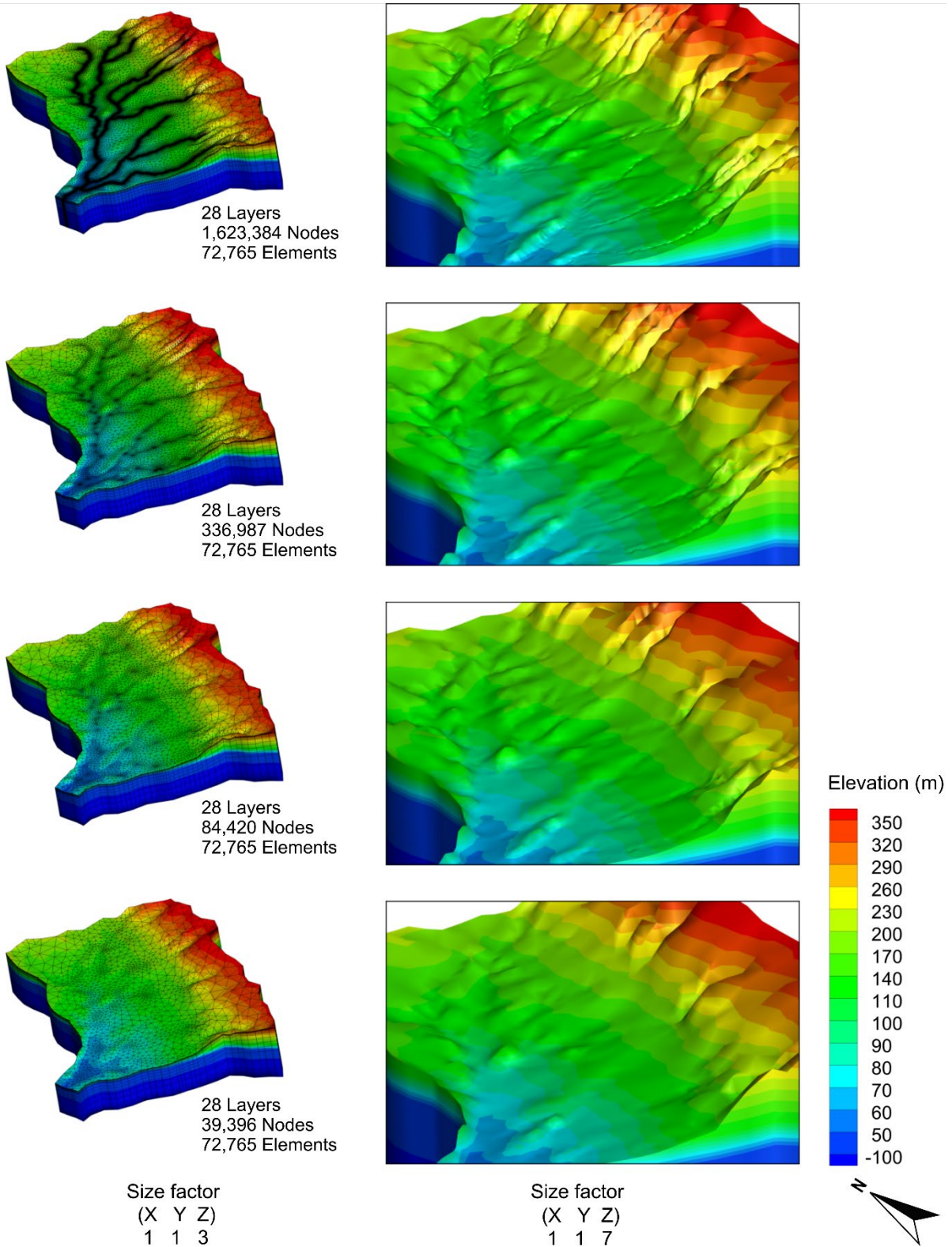
Figure SI1: Selection of a set of tested 3D meshes showing the impact of the 2D discretization on the topography representation from fine to coarse (top to bottom). The figures on the left have the mesh mapped to provide a visual of the discretization around the streams. The right column shows a zoomed view of the catchment with a larger vertical exaggeration and without the grid to provide a better view of the resulting topography. A summary of the total number of layers, nodes, and elements is provided for each 3D mesh.

2   Testing the drained model against groundwater level

Data for groundwater levels were obtained from the Government of South Australia (https://www.waterconnect.sa.gov.au/) for the McLaren Vale prescribed well area. We selected wells that range in depth from 0-30 m. From a total of 393 wells in the area (Figure SI2a and c) we filtered wells with at least 3 observations from the year 2000 onwards. A total of 47 wells meet the selection criteria (Figure SI2 b and d).

With the simulation starting in January (the hottest month) we assumed completely dry initial conditions for the surface domain. The completely saturated model was drained as an iterative process, comparing the modelled groundwater heads until they matched average observed water level in representative locations as well as possible (Figure SI3). The water table was then used as an initial condition for all scenarios.
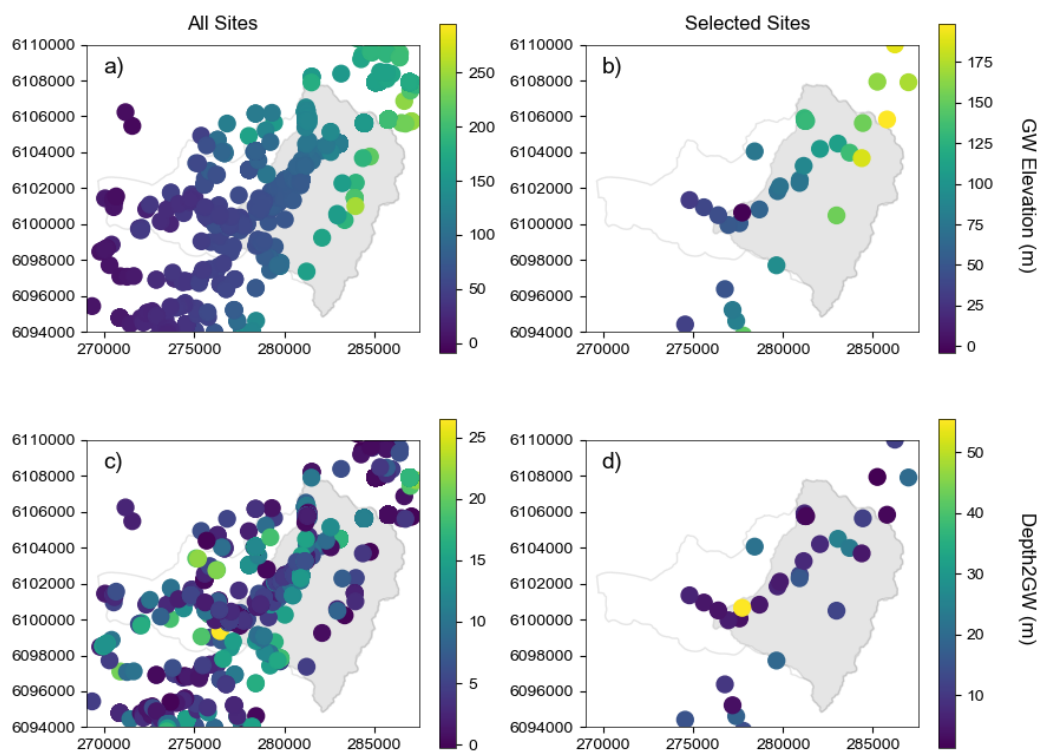
Figure SI2. Available groundwater data within the study area. Groundwater elevation was converted to depth to water using extrapolated surface elevations.
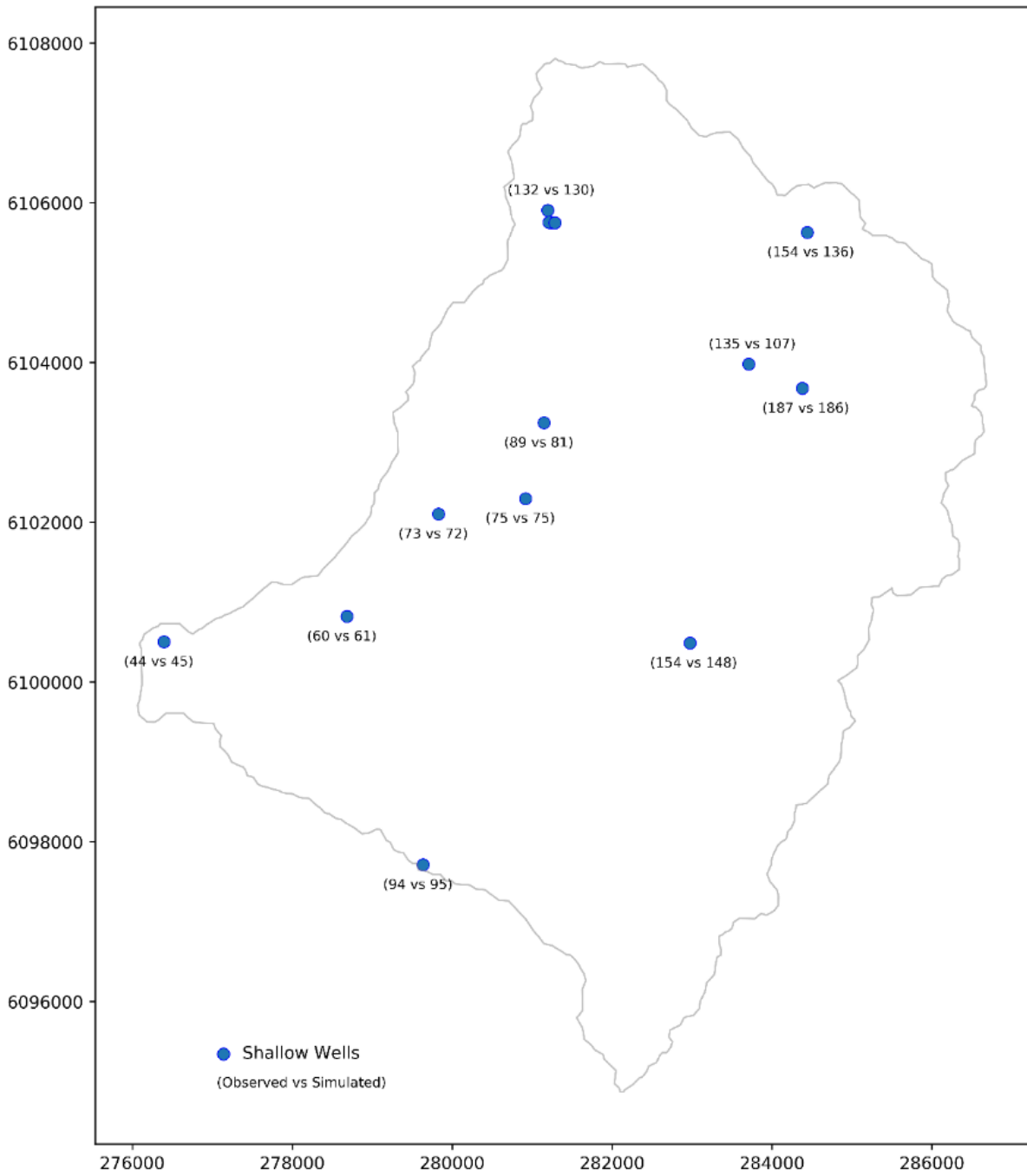
Figure SI3. Comparison of average observed groundwater elevation and simulated initial conditions after the fully saturated model domain was drained.

3   Detailed simulated Water Balance and Evapotranspiration (ET) results

Across scenarios the largest component of the water balance was the fluid transfer (FT) which accounted on average for over 35% with values ranging from 34-38% (Figure and Table SI1). The average porous media (PM) and ET were ≈26 and 22% with values ranging from 25-28% and 18-24% respectively. The overland flow (OLF) component ranged from 11-16% and the critical depth (surface outflow at the model outlet) accounted roughly for <2%. Random errors were noted in all the simulations, however, the overall total error accounted for less than 0.5% of the total water balance in all the scenarios. Among the scenarios with different sets of hydraulic properties (scenarios 1 through 4), scenarios 2&3 showed practically the same results and scenarios 1&4 were in close agreement (1-3% differences for some components). The largest difference between scenarios 2&3 and 1&4 was reflected in the porous media component with an average difference of over 12%.

Another difference between the set of scenarios 1-4 and scenario 8 was observed in the partition of the total evapotranspiration components (Figure and Table SI2). Across all the scenarios the largest component was the PM evaporation with 41-42%. However, surface evaporation accounted for 36% and PM transpiration for 23% for scenarios 1-4, while for scenario 8 the second ET component was PM transpiration with 34% followed by surface evaporation with 25%.
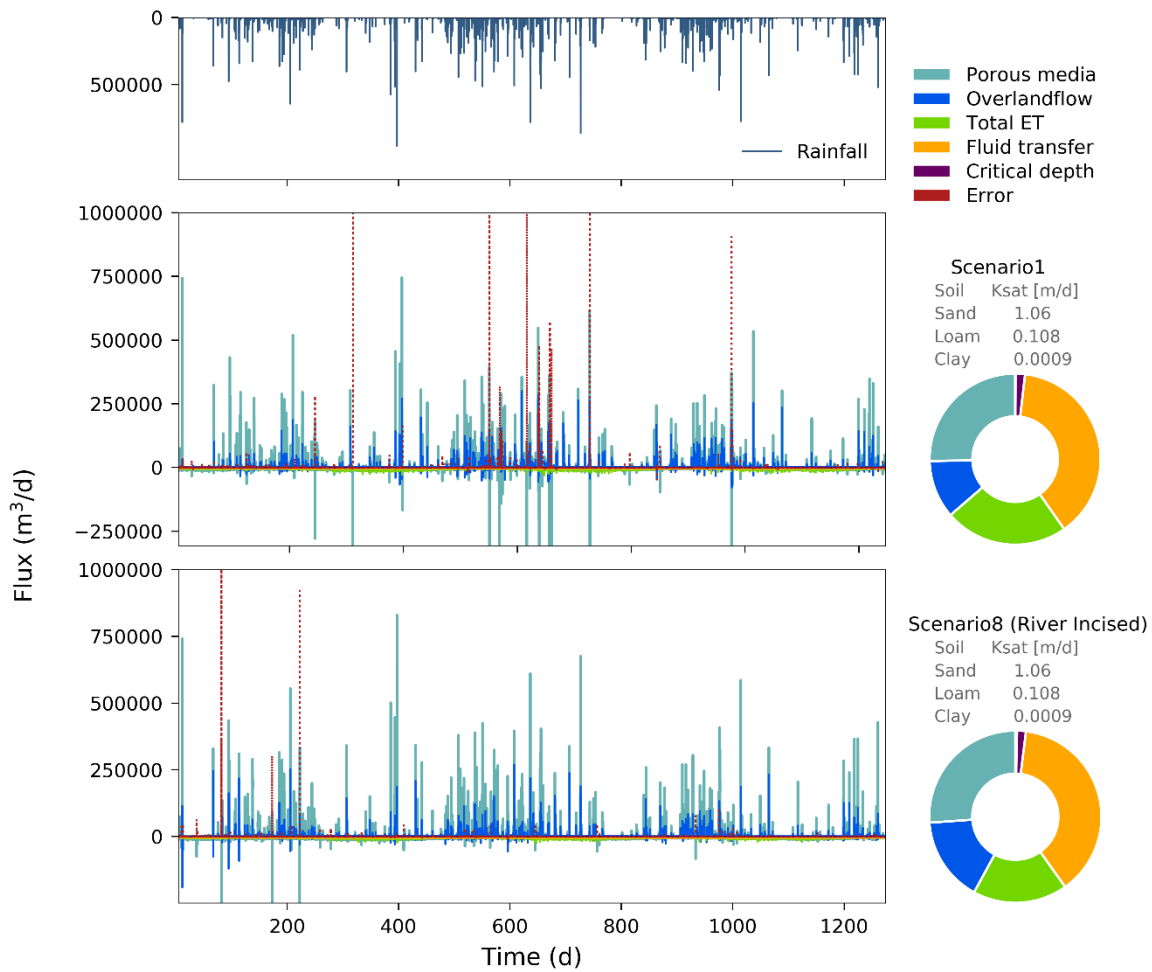
Figure SI4: Water balance for scenario 1 and 8 as a breakdown of the rainfall input. The pie chart shows the proportional contribution in percentage of each water balance component

Table SI1: Breakdown of the proportional contributions the water balance components as a percentage for all scenarios.

Scenario	1	Sc2	Sc3	Sc4	Sc8
Porous Media	25.38	27.69	27.6	25.41	26.11
Overland Flow	10.97	12.58	12.48	11.35	15.94
Total ET	23.39	23.6	23.6	23.14	17.79
Fluid Transfer	38.39	34.14	34.4	38.3	38.18
Critical Depth	1.78	1.6	1.62	1.74	1.67
Error	0.08	0.38	0.3	0.06	0.31
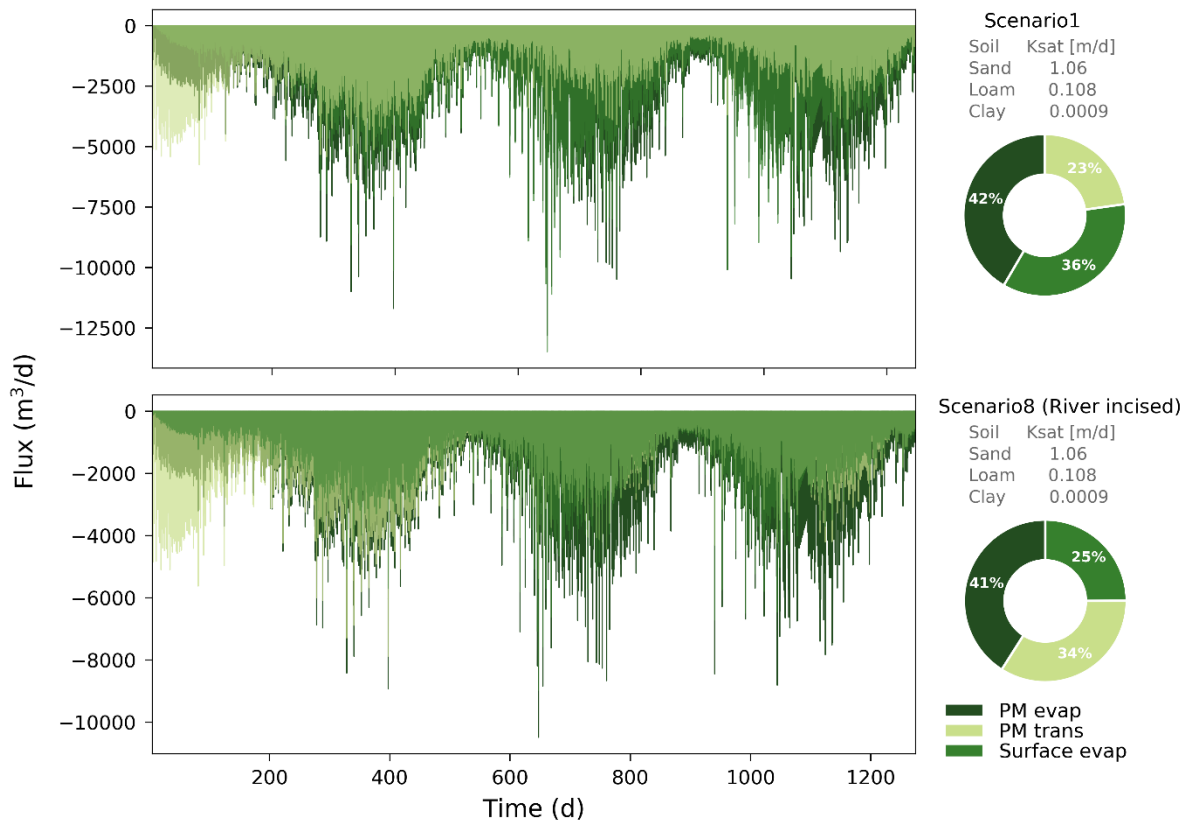
Figure SI5: Simulated evapotranspiration components for scenarios 1 and 8. The pie chart shows the breakdown of the proportional contribution in percentage of each ET component.

Table SI2: Breakdown of the proportional contributions the ET components as a percentage of total ET for all scenarios.

Scenario	1	2	3	4	8
PM Evap	41.59	41.91	41.92	41.56	41.01
PM Transp	35.63	34.82	35.07	36.05	34.02
Surface Evap	24.95	23.26	22.99	22.37	24.95