Appendix: Summary of flow simulations under reference and anthropogenic conditions

Modelled flow estimates from 3447 stream reaches in five catchments in Southern California were summarized to quantify stream miles under different hydrologic conditions. Flow estimates were based on reference scenarios under historical, non-impacted land use conditions. Monthly flow was estimated for dry, normal, and wet years. Likelihood of flow conditions inflating, diminishing, or remaining stable under present-day land cover was also summarized for each watershed.

Historic flows were estimated to be highest in the high elevations of the San Gabriel, San Bernardino, and San Jacinto mountains, while the lowest flows were in the inland valleys (Figure 1). Flow estimates for the Upper Santa Ana were generally higher than those for the Lower Santa Ana. Flow estimates also increased as expected under different climate conditions such that greater flow was estimated during wet years.

Estimates were highest during winter to early spring (January through April) when estimated flows > 100 cfs were more common, across all watersheds (Figure 2, Table 1). Similarly, low flows < 1 cfs were more common during the summer and fall. Unsurprisingly, flows were higher in wet conditions than dry, although this impact was more obvious in some watersheds (e.g., Upper Santa Ana) than others (e.g., Lower Santa Ana). Late summer flows over 10 cfs were limited to small portions of the region—and nearly eliminated from certain watersheds (e.g., San Jacinto, Lower Santa Ana), even in wet years.

Diminishing flow was the most common prediction under anthropogenic conditions, although some exceptions were observed (Figure 3, Table 2). Stream reaches were more likely to remain stable during the winter, particularly in December. Flow conditions were also more likely to be stable during wet years. Interestingly, stream conditions in January under normal precipitation were most likely to be inflated, whereas conditions were expected to be stable during wet years. Patterns between catchments were generally consistent.

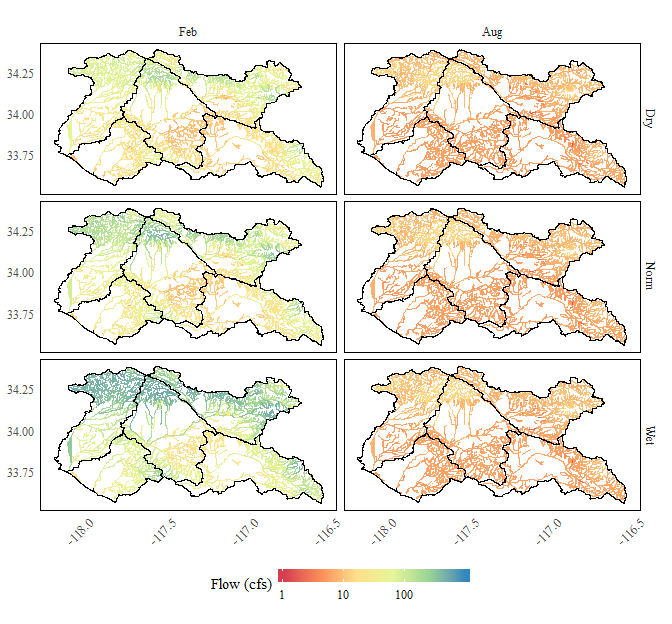


Figure 1: Estimated flow under historic (reference) conditions.

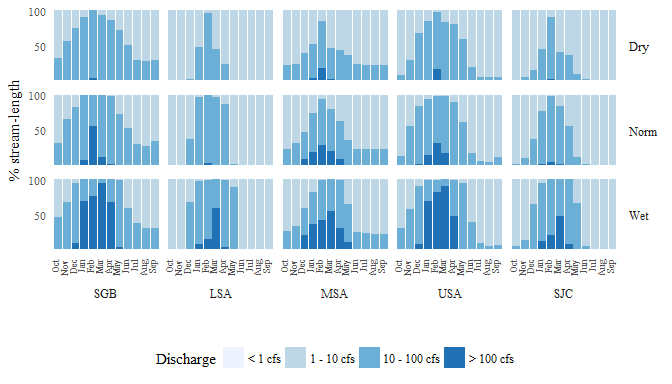


Figure 2: Percent of stream length for the estimated discharge (< 1 cfs, 1 - 10 cfs, 10 - 100 cfs, > 100 cfs) under reference conditions. Discharges were also estimated for different climate scenarios for years that were dry, normal, or wet. SGB: San Gabriel; LSA: Lower Santa Ana; MSA: Middle Santa Ana; USA: Upper Santa Ana; and SJC: San Jacinto.

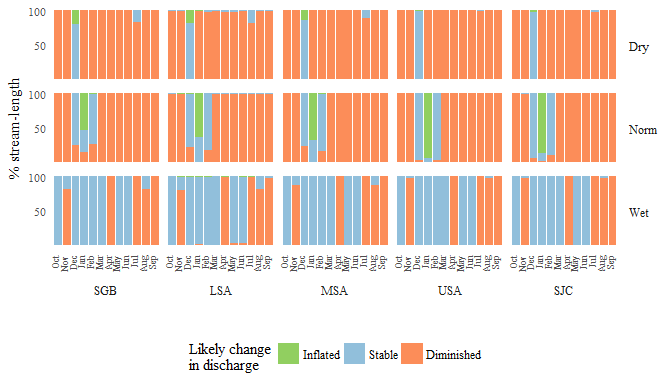


Figure 3: Percent of stream length for the estimated likelihood of a change in discharge as inflating, remaining stable, or diminishing under anthropogenic conditions. Likelihoods were estimated for different climate scenarios for years that were dry, normal, or wet. SGB: San Gabriel; LSA: Lower Santa Ana; MSA: Middle Santa Ana; USA: Upper Santa Ana; and SJC: San Jacinto.

*Table 1. Stream-length (km) in flow classes in each watershed, by month and climate condition. Flows are in cfs.* Dashes indicate zero values.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Dry | | | |  | Normal | | | |  | Wet | | | |
| Watershed | | < 1 | 1 - 10 | 10 - 100 | > 100 |  | < 1 | 1 - 10 | 10 - 100 | > 100 |  | < 1 | 1 - 10 | 10 - 100 | > 100 |
| *San Gabriel* | | |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Oct | -- | 8.07 | 3.79 | -- |  | -- | 8.12 | 3.73 | -- |  | -- | 6.45 | 5.41 | -- |
|  | Nov | -- | 5.18 | 6.68 | -- |  | -- | 4.18 | 7.68 | -- |  | -- | 3.83 | 8.03 | -- |
|  | Dec | -- | 2.97 | 8.89 | -- |  | -- | 2.09 | 9.75 | 0.02 |  | -- | 0.62 | 10.25 | 0.99 |
|  | Jan | -- | 1.16 | 10.70 | -- |  | -- | 0.01 | 10.98 | 0.86 |  | -- | 0.01 | 3.67 | 8.19 |
|  | Feb | -- | 0.01 | 11.44 | 0.40 |  | -- | -- | 5.26 | 6.59 |  | -- | -- | 2.88 | 8.98 |
|  | Mar | -- | 0.77 | 11.09 | -- |  | -- | 0.01 | 10.54 | 1.31 |  | -- | -- | 0.58 | 11.27 |
|  | Apr | -- | 1.72 | 10.14 | -- |  | -- | 0.15 | 11.52 | 0.19 |  | -- | -- | 3.86 | 7.99 |
|  | May | -- | 3.33 | 8.53 | -- |  | -- | 3.30 | 8.55 | -- |  | -- | 0.15 | 11.29 | 0.42 |
|  | Jun | -- | 5.83 | 6.03 | -- |  | -- | 5.71 | 6.14 | -- |  | -- | 4.82 | 7.04 | -- |
|  | Jul | -- | 8.41 | 3.45 | -- |  | -- | 8.30 | 3.55 | -- |  | -- | 7.35 | 4.50 | -- |
|  | Aug | -- | 8.55 | 3.31 | -- |  | -- | 8.74 | 3.12 | -- |  | -- | 8.25 | 3.61 | -- |
|  | Sep | -- | 8.33 | 3.52 | -- |  | -- | 7.79 | 4.06 | -- |  | -- | 8.35 | 3.51 | -- |
| *Lower Santa Ana* | | |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Oct | 0.01 | 7.22 | -- | -- |  | 0.01 | 7.22 | -- | -- |  | 0.01 | 7.22 | -- | -- |
|  | Nov | 0.01 | 7.22 | -- | -- |  | 0.01 | 7.22 | -- | -- |  | 0.01 | 7.22 | -- | -- |
|  | Dec | -- | 7.10 | 0.14 | -- |  | -- | 4.58 | 2.65 | -- |  | -- | 2.40 | 4.84 | -- |
|  | Jan | -- | 3.77 | 3.47 | -- |  | -- | 0.18 | 7.05 | -- |  | -- | 0.15 | 6.52 | 0.57 |
|  | Feb | -- | 0.23 | 7.01 | -- |  | -- | 0.07 | 6.98 | 0.18 |  | -- | 0.05 | 6.17 | 1.01 |
|  | Mar | -- | 3.98 | 3.26 | -- |  | -- | 0.24 | 6.99 | -- |  | -- | 0.01 | 2.98 | 4.25 |
|  | Apr | -- | 5.50 | 1.74 | -- |  | -- | 1.00 | 6.24 | -- |  | -- | 0.06 | 6.95 | 0.23 |
|  | May | -- | 7.21 | 0.03 | -- |  | -- | 7.12 | 0.11 | -- |  | -- | 0.81 | 6.42 | -- |
|  | Jun | 0.01 | 7.22 | -- | -- |  | 0.01 | 7.22 | -- | -- |  | -- | 7.24 | -- | -- |
|  | Jul | 0.01 | 7.22 | -- | -- |  | 0.01 | 7.22 | -- | -- |  | 0.01 | 7.22 | -- | -- |
|  | Aug | 0.01 | 7.22 | -- | -- |  | 0.01 | 7.22 | -- | -- |  | 0.01 | 7.22 | -- | -- |
|  | Sep | 0.01 | 7.22 | -- | -- |  | 0.01 | 7.22 | -- | -- |  | 0.01 | 7.22 | -- | -- |
| *Middle Santa Ana* | | |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Oct | -- | 10.30 | 2.96 | -- |  | -- | 10.30 | 2.96 | -- |  | -- | 9.91 | 3.34 | -- |
|  | Nov | -- | 10.18 | 3.08 | -- |  | -- | 9.18 | 4.08 | -- |  | -- | 8.92 | 4.34 | -- |
|  | Dec | -- | 8.05 | 5.21 | -- |  | -- | 7.05 | 5.15 | 1.06 |  | -- | 5.38 | 5.16 | 2.72 |
|  | Jan | -- | 6.31 | 6.55 | 0.40 |  | -- | 3.41 | 7.36 | 2.49 |  | -- | 2.45 | 6.11 | 4.70 |
|  | Feb | -- | 2.06 | 8.94 | 2.26 |  | -- | 0.76 | 8.83 | 3.67 |  | 0.01 | 0.08 | 7.72 | 5.46 |
|  | Mar | -- | 7.06 | 5.91 | 0.30 |  | -- | 2.66 | 8.07 | 2.53 |  | 0.01 | 0.03 | 6.01 | 7.21 |
|  | Apr | -- | 7.52 | 5.65 | 0.09 |  | -- | 5.04 | 7.09 | 1.12 |  | 0.01 | 0.10 | 9.10 | 4.05 |
|  | May | -- | 8.49 | 4.77 | -- |  | -- | 8.51 | 4.74 | -- |  | -- | 4.79 | 7.15 | 1.32 |
|  | Jun | -- | 10.23 | 3.03 | -- |  | -- | 10.23 | 3.03 | -- |  | -- | 10.01 | 3.25 | -- |
|  | Jul | -- | 10.33 | 2.93 | -- |  | -- | 10.33 | 2.93 | -- |  | -- | 10.30 | 2.96 | -- |
|  | Aug | -- | 10.33 | 2.93 | -- |  | -- | 10.33 | 2.93 | -- |  | -- | 10.33 | 2.93 | -- |
|  | Sep | -- | 10.33 | 2.93 | -- |  | -- | 10.22 | 3.04 | -- |  | -- | 10.33 | 2.93 | -- |
| *Upper Santa Ana* | | |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Oct | -- | 14.02 | 1.10 | -- |  | 0.01 | 13.27 | 1.83 | -- |  | 0.01 | 10.53 | 4.58 | -- |
|  | Nov | -- | 10.81 | 4.31 | -- |  | -- | 6.75 | 8.31 | 0.05 |  | -- | 6.57 | 8.55 | -- |
|  | Dec | -- | 4.80 | 10.32 | -- |  | -- | 2.46 | 12.53 | 0.13 |  | -- | 1.43 | 12.56 | 1.12 |
|  | Jan | -- | 2.30 | 12.74 | 0.07 |  | -- | 0.83 | 12.27 | 2.03 |  | -- | 0.19 | 4.64 | 10.29 |
|  | Feb | -- | 0.26 | 12.49 | 2.37 |  | -- | 0.19 | 10.23 | 4.70 |  | 0.01 | 0.13 | 2.70 | 12.28 |
|  | Mar | -- | 2.58 | 12.54 | -- |  | -- | 0.30 | 12.26 | 2.55 |  | 0.01 | 0.07 | 1.39 | 13.65 |
|  | Apr | -- | 3.01 | 12.11 | -- |  | -- | 1.54 | 13.55 | 0.03 |  | -- | 0.15 | 7.89 | 7.07 |
|  | May | -- | 6.17 | 8.95 | -- |  | -- | 5.81 | 9.31 | -- |  | -- | 0.84 | 14.20 | 0.08 |
|  | Jun | -- | 12.25 | 2.87 | -- |  | -- | 12.56 | 2.56 | -- |  | -- | 9.20 | 5.92 | -- |
|  | Jul | -- | 14.30 | 0.82 | -- |  | -- | 14.34 | 0.78 | -- |  | -- | 13.85 | 1.27 | -- |
|  | Aug | 0.01 | 14.43 | 0.68 | -- |  | 0.01 | 14.46 | 0.65 | -- |  | 0.01 | 14.39 | 0.72 | -- |
|  | Sep | 0.01 | 14.43 | 0.68 | -- |  | 0.01 | 13.39 | 1.72 | -- |  | 0.01 | 14.31 | 0.80 | -- |
| *San Jacinto* | | |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Oct | -- | 11.42 | 0.05 | -- |  | -- | 11.42 | 0.05 | -- |  | -- | 10.95 | 0.53 | -- |
|  | Nov | -- | 10.92 | 0.56 | -- |  | -- | 10.36 | 1.12 | -- |  | -- | 9.93 | 1.54 | -- |
|  | Dec | -- | 9.75 | 1.72 | -- |  | -- | 7.23 | 4.24 | -- |  | -- | 4.06 | 7.41 | -- |
|  | Jan | -- | 6.32 | 5.15 | -- |  | -- | 2.66 | 8.63 | 0.18 |  | -- | 0.57 | 9.56 | 1.35 |
|  | Feb | -- | 1.06 | 10.11 | 0.30 |  | -- | 0.24 | 10.78 | 0.44 |  | -- | -- | 9.23 | 2.24 |
|  | Mar | -- | 6.77 | 4.70 | -- |  | -- | 1.80 | 9.52 | 0.15 |  | -- | -- | 6.07 | 5.41 |
|  | Apr | -- | 7.33 | 4.15 | -- |  | -- | 5.17 | 6.30 | -- |  | -- | -- | 10.68 | 0.80 |
|  | May | -- | 10.47 | 1.01 | -- |  | -- | 10.15 | 1.32 | -- |  | -- | 3.86 | 7.61 | -- |
|  | Jun | -- | 11.24 | 0.23 | -- |  | -- | 11.28 | 0.20 | -- |  | -- | 10.90 | 0.58 | -- |
|  | Jul | -- | 11.47 | -- | -- |  | -- | 11.47 | -- | -- |  | -- | 11.38 | 0.09 | -- |
|  | Aug | -- | 11.47 | -- | -- |  | -- | 11.47 | -- | -- |  | -- | 11.44 | 0.03 | -- |
|  | Sep | -- | 11.47 | -- | -- |  | -- | 11.45 | 0.03 | -- |  | -- | 11.47 | -- | -- |

Table 2. Stream-length (km) in flow alteration class in each watershed, by month and climate condition. Inflated: Probability that flow is increased from historic conditions ≥ 0.9. Diminished: Probability that flow is decreased from historic conditions ≥ 0.9. Stable: Probability that flow has neither increased nor decreased from historic conditions ≥ 0.8. Dashes indicate zero values.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Dry | | |  | Normal | | |  | Wet | | |
| Watershed | | Inflated | Stable | Diminished |  | Inflated | Stable | Diminished |  | Inflated | Stable | Diminished |
| *San Gabriel* | | |  |  |  |  |  |  |  |  |  |  |
|  | Oct | -- | -- | 11.9 |  | -- | -- | 11.9 |  | -- | 11.9 | -- |
|  | Nov | -- | -- | 11.9 |  | -- | -- | 11.9 |  | -- | 2.1 | 9.7 |
|  | Dec | 2.3 | 9.6 | -- |  | -- | 8.8 | 3.0 |  | -- | 11.9 | -- |
|  | Jan | -- | -- | 11.9 |  | 6.3 | 3.7 | 1.8 |  | -- | 11.9 | -- |
|  | Feb | -- | -- | 11.9 |  | 0.1 | 8.7 | 3.1 |  | -- | 11.9 | -- |
|  | Mar | -- | -- | 11.9 |  | -- | -- | 11.9 |  | -- | 11.9 | -- |
|  | Apr | -- | -- | 11.9 |  | -- | -- | 11.9 |  | -- | -- | 11.9 |
|  | May | -- | -- | 11.9 |  | -- | -- | 11.9 |  | -- | 11.9 | -- |
|  | Jun | -- | -- | 11.9 |  | -- | -- | 11.9 |  | -- | 11.8 | -- |
|  | Jul | -- | 2.1 | 9.8 |  | -- | -- | 11.9 |  | -- | -- | 11.9 |
|  | Aug | -- | -- | 11.9 |  | -- | -- | 11.9 |  | -- | 2.1 | 9.7 |
|  | Sep | -- | -- | 11.9 |  | -- | -- | 11.9 |  | -- | -- | 11.9 |
| *Lower Santa Ana* | | |  |  |  |  |  |  |  |  |  |  |
|  | Oct | -- | -- | 7.2 |  | -- | -- | 7.2 |  | -- | 7.2 | -- |
|  | Nov | -- | -- | 7.2 |  | -- | 0.1 | 7.1 |  | -- | 1.4 | 5.8 |
|  | Dec | 1.3 | 5.9 | -- |  | -- | 5.6 | 1.6 |  | -- | 7.2 | -- |
|  | Jan | -- | -- | 7.2 |  | 4.5 | 2.7 | -- |  | -- | 7.1 | 0.1 |
|  | Feb | -- | 0.1 | 7.1 |  | -- | 5.9 | 1.3 |  | -- | 7.2 | -- |
|  | Mar | -- | -- | 7.2 |  | -- | -- | 7.2 |  | -- | 7.2 | -- |
|  | Apr | -- | 0.1 | 7.1 |  | -- | -- | 7.2 |  | -- | -- | 7.2 |
|  | May | -- | 0.1 | 7.1 |  | -- | 0.1 | 7.1 |  | -- | 7.0 | 0.2 |
|  | Jun | -- | -- | 7.2 |  | -- | -- | 7.2 |  | -- | 7.0 | 0.2 |
|  | Jul | -- | 1.3 | 5.9 |  | -- | -- | 7.2 |  | -- | -- | 7.2 |
|  | Aug | -- | -- | 7.2 |  | -- | -- | 7.2 |  | -- | 1.4 | 5.9 |
|  | Sep | -- | -- | 7.2 |  | -- | -- | 7.2 |  | -- | 0.1 | 7.1 |
| *Middle Santa Ana* | | |  |  |  |  |  |  |  |  |  |  |
|  | Oct | -- | -- | 13.3 |  | -- | -- | 13.3 |  | -- | 13.3 | -- |
|  | Nov | -- | -- | 13.3 |  | -- | -- | 13.3 |  | -- | 1.5 | 11.7 |
|  | Dec | 1.9 | 11.4 | -- |  | -- | 10.1 | 3.1 |  | -- | 13.3 | -- |
|  | Jan | -- | -- | 13.3 |  | 8.9 | 4.2 | 0.1 |  | -- | 13.3 | -- |
|  | Feb | -- | -- | 13.3 |  | 0.1 | 11.0 | 2.2 |  | -- | 13.3 | -- |
|  | Mar | -- | -- | 13.3 |  | -- | -- | 13.3 |  | -- | 13.3 | -- |
|  | Apr | -- | -- | 13.3 |  | -- | -- | 13.3 |  | -- | -- | 13.3 |
|  | May | -- | -- | 13.3 |  | -- | -- | 13.3 |  | -- | 13.3 | -- |
|  | Jun | -- | -- | 13.3 |  | -- | -- | 13.3 |  | -- | 13.2 | 0.1 |
|  | Jul | -- | 1.6 | 11.7 |  | -- | -- | 13.3 |  | -- | -- | 13.3 |
|  | Aug | -- | -- | 13.3 |  | -- | -- | 13.3 |  | -- | 1.6 | 11.7 |
|  | Sep | -- | -- | 13.3 |  | -- | -- | 13.3 |  | -- | -- | 13.3 |
| *Upper Santa Ana* | | |  |  |  |  |  |  |  |  |  |  |
|  | Oct | -- | -- | 15.1 |  | -- | -- | 15.1 |  | -- | 15.1 | -- |
|  | Nov | -- | -- | 15.1 |  | -- | -- | 15.1 |  | -- | 0.3 | 14.9 |
|  | Dec | 0.3 | 14.9 | -- |  | -- | 14.6 | 0.5 |  | -- | 15.1 | -- |
|  | Jan | -- | -- | 15.1 |  | 14.2 | 0.8 | 0.1 |  | -- | 15.1 | -- |
|  | Feb | -- | -- | 15.1 |  | -- | 14.5 | 0.6 |  | -- | 15.1 | -- |
|  | Mar | -- | -- | 15.1 |  | -- | -- | 15.1 |  | -- | 15.1 | -- |
|  | Apr | -- | -- | 15.1 |  | -- | -- | 15.1 |  | -- | -- | 15.1 |
|  | May | -- | -- | 15.1 |  | -- | -- | 15.1 |  | -- | 15.1 | -- |
|  | Jun | -- | -- | 15.1 |  | -- | -- | 15.1 |  | -- | 15.0 | 0.1 |
|  | Jul | -- | 0.2 | 14.9 |  | -- | -- | 15.1 |  | -- | -- | 15.1 |
|  | Aug | -- | -- | 15.1 |  | -- | -- | 15.1 |  | -- | 0.3 | 14.9 |
|  | Sep | -- | -- | 15.1 |  | -- | -- | 15.1 |  | -- | -- | 15.1 |
| *San Jacinto* | | |  |  |  |  |  |  |  |  |  |  |
|  | Oct | -- | -- | 11.5 |  | -- | -- | 11.5 |  | -- | 11.5 | -- |
|  | Nov | -- | -- | 11.5 |  | -- | -- | 11.4 |  | -- | 0.3 | 11.2 |
|  | Dec | 0.3 | 11.2 | -- |  | -- | 10.8 | 0.7 |  | -- | 11.5 | -- |
|  | Jan | -- | -- | 11.5 |  | 9.9 | 1.4 | 0.1 |  | -- | 11.5 | -- |
|  | Feb | -- | -- | 11.4 |  | -- | 10.3 | 1.2 |  | -- | 11.5 | -- |
|  | Mar | -- | -- | 11.5 |  | -- | -- | 11.5 |  | -- | 11.5 | -- |
|  | Apr | -- | -- | 11.4 |  | -- | -- | 11.5 |  | -- | -- | 11.5 |
|  | May | -- | -- | 11.4 |  | -- | -- | 11.5 |  | -- | 11.4 | -- |
|  | Jun | -- | -- | 11.5 |  | -- | -- | 11.5 |  | -- | 11.4 | -- |
|  | Jul | -- | 0.2 | 11.2 |  | -- | -- | 11.5 |  | -- | -- | 11.5 |
|  | Aug | -- | -- | 11.5 |  | -- | -- | 11.5 |  | -- | 0.2 | 11.2 |
|  | Sep | -- | -- | 11.5 |  | -- | -- | 11.5 |  | -- | -- | 11.5 |