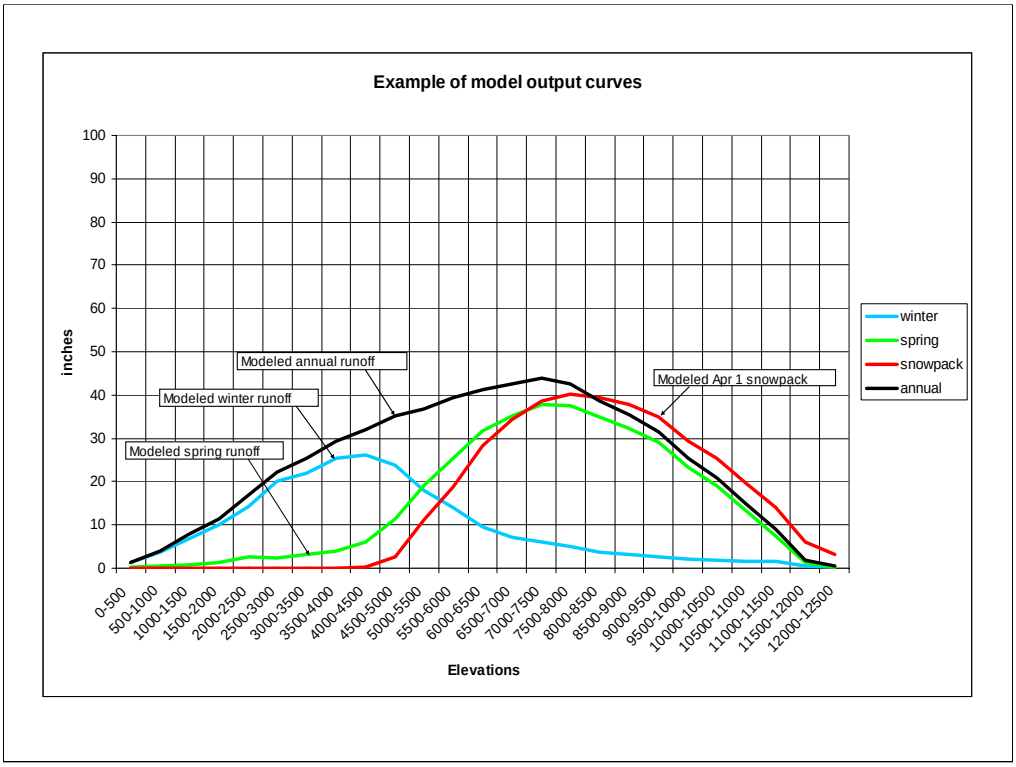
# Climatic Change Implications for Hydrologic Systems in the Sierra Nevada

## Part Four:

## Sample Model Results by Study Region Using Equal Weighted HRU's

Part 4 is authored by Chuck Watson, WRC Environmental.




For characterizing hydrologic implications of GW at the scale of the Sierra Nevada and the three Study Regions, the Yield Processor, based on HRU's, was used to further generalize runoff process relationships in terms of EW-HRU's

**EW-HRU**'s ("Equal Weighted - Hydrologic Response Units") assumes that every 500 foot elevation interval has the same watershed area through the entire 0-12,500 foot elevation spectrum and each elevation interval has equal proportions of each of the generalized aspect-vegetation-soil HRU's. This approach provide a schematic representation of hydrologic process relationships along an elevation profile in each Study Region of the Sierra Nevada.

The interpretation of EW-HRU modeled outputs includes:

- First, the **modeled output curves** were categorized into **runoff types** and significant snowpack relationships.

-Second, the runoff types and significant snowpack relationships were combined into **runoff domains** that have relatively consistent suites of runoff types.

**Modeled Output Curves;**

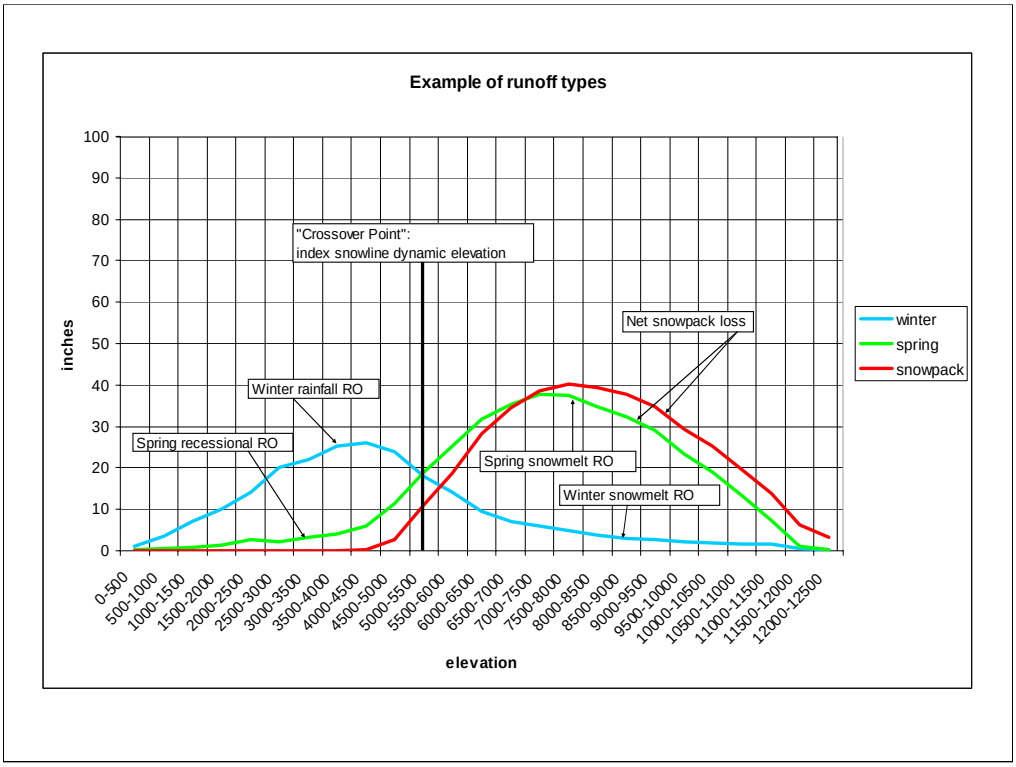
The modeled output curves are the EW-HRU runoff and snowpack relations as produced by the Yield Processor.

**Modeled winter season runoff** represents the modeled elevation distribution of runoff that occurs over the total of the winter season (October-March inclusive; 181 days)

**Modeled spring season runoff** represents the modeled elevation distribution of runoff that occurs over the total of the spring season (April-July inclusive; 122 days)

**Modeled total runoff** represents the modeled elevation distribution of the combined winter and spring season runoff (October-July inclusive; 303 days)

**Modeled April 1st snowpack** represents the modeled elevation distribution of the standing snowpack in inches of water content




**Runoff Types;**

The modeled output curves were separated into runoff types designed to reflect basic watershed runoff processes

**Winter rainfall runoff** is the runoff generated mostly by winter rain storms and includes the modeled winter season runoff below the crossover point and some winter season snowmelt at elevations near the crossover point

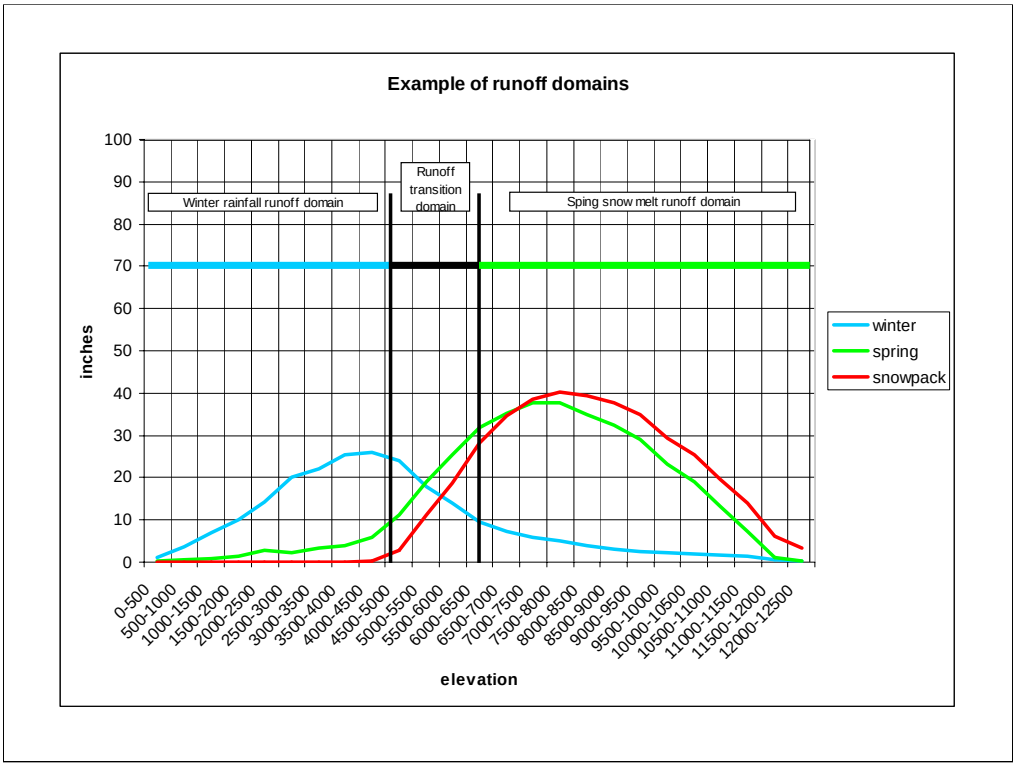
**Winter snowmelt runoff** is the runoff generated mostly by winter season snowmelt within the lower elevations of the snowpack zone and includes the modeled winter season runoff above the crossover point and may include some winter rainfall runoff from warm storms as well as from the over-winter drainage of soils and geologic units.

**Spring recessional runoff** is the runoff generated mostly by mechanisms of soil-water drainage from saturated conditions charged by winter rain storms or the infiltration from winter season snowmelt at lower snowpack elevations.

**Spring snowmelt runoff** is the runoff generated primarily by spring season melting of the modeled April 1st snowpack.

**Index snowline dynamic elevation** is an elevation around which (a range of possibly 2000 ft) rain-on-snow events are more probable. It is here arbitrarily set at the crossover point of the modeled winter season runoff curve and modeled spring season runoff curve.

**Net snowpack loss** is the magnitude of water content of the modeled April 1st snowpack curve when that curve has a higher magnitude of the modeled spring season runoff curve. This is snowpack water content that is not reflected in spring snowmelt runoff.



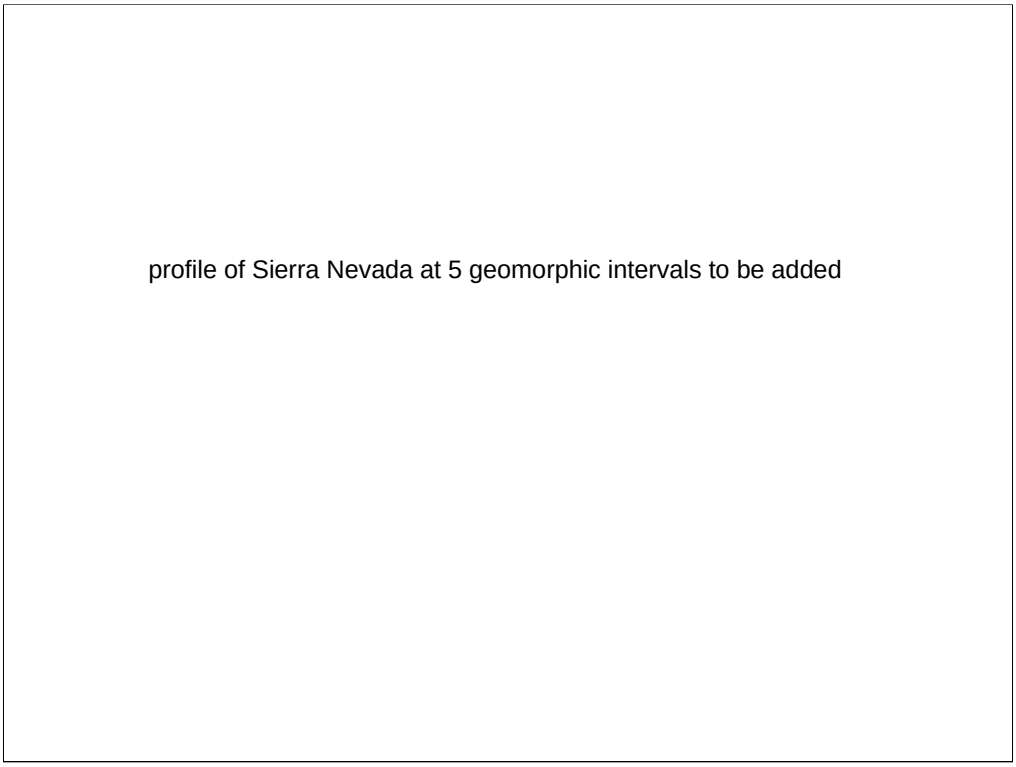

**Runoff Domains;**

Runoff domains are identified by consistent patterns of the runoff types and the significant snowpack relationships.

**Winter rainfall runoff domain** includes the elevation interval where *winter rainfall runoff* rates predominate over *spring recessional runoff* rates and snowpack is not a factor.

**Runoff transition domain** includes the elevation interval where, with increasing elevation, winter season runoff rates decrease rapidly and spring season runoff increase rapidly. It contains the crossover point, the *index snowline dynamic elevation*, and most of the rain-on-snow elevation interval.

**Spring snowmelt runoff domain** includes the elevation interval where *spring snowmelt runoff* dominates over *winter snowmelt runoff*. Often the upper elevations of this domain includes areas of *net snowpack loss*.



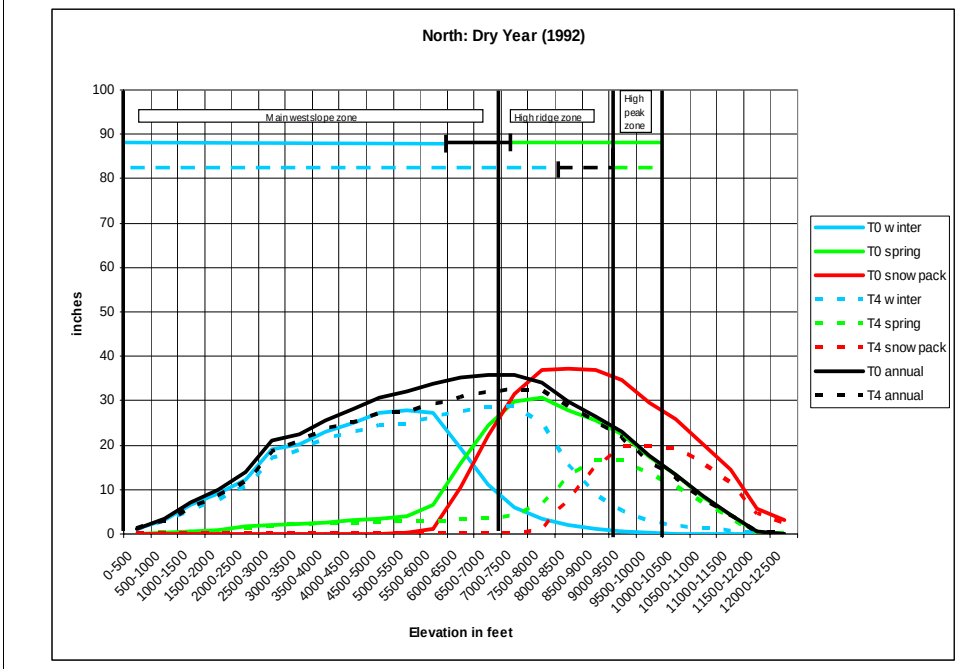

**Watershed Elevation Zones:** Each of the three Study Regions were diviced into four elevation interval that reflect major watershed-topographic relationships that have significant bearing on waterhsed runoff and yield:

**Central Valley Zone** includes those lower elevations that are below the topographic margin separating the Sierra Nevada and the Central Valley and are not relevant to the hydrologic processes in the Study Regions.

**Main Westslope Zone** is the main area of westslope watersheds that usually includes the full spectrum of Sierra Nevada geomorphology and produces most of the runoff from main-trunk watersheds.

**High Ridge Zone** is that portion which represents the main crest area, including many of the peaks and major interior ridges of main-trunk watershed, and is estimated to be about 5-15% of main-trunk watershed area providing significant runoff to only higher secondary watersheds .

**High Peak Zone** is that portion which represents only the extreme elevations and the highest peaks of the crest areas of main-trunk watersheds, and is estimated to be <5% of main-trunk watersheds providing significant runoff to only the highest alpine meadows and lakes.




North-Sierra Nevada Region: Dry Wateryear:

1) Summary of Changes:

Below about 5750 ft, conditions associated with 4dC warming do not result in any significant hydrologic changes. However major hydrologic changes do occur between about 5750 and 8250 ft. In this elevation interval, winter rainfall RO replaces spring snowmelt RO as the dominant runoff process. Also in this elevation interval, spring recessional RO are significantly reduced as is the potential for summer baseflows. Modeled April 1st snowpack moves to higher elevations and is significantly reduced in water content. Net snowpack loss decreases significantly in magnitude and the elevation interval of occurrence is lessened, moving to the highest elevation interval in the North-Study Region (9000-10,000 ft). Between about 8250 and 10,000 ft spring snowmelt RO remains the dominant runoff process, however there is a significant increase in winter snowmelt RO and decrease in spring snowmelt RO throughout. Decreases in modeled annual RO occur between 2000 and 8000 ft.

April 1st snowpack regime:

- Shifts 2000 ft higher and decreases significantly in water content, due to increased elevations of rainfall storms and advanced-season snowmelt
- Shifts;
    - from the highest portion of the Main Westslope Zone and above
    - to the highest portion of the High Ridge Zone and above
- Reduced water content implies that the completion of snowpack melt will occur at an earlier date and the summer baseflow season will be longer in the upper Main Westslope Zone and above

0 to 5750 ft: runoff patterns change slightly in the lower and middle Main Westslope Zone:

- Winter rainfall RO is slightly decreased due to increased losses by evapotranspiration demand
- Total RO decreases slightly due to increased evapotranspiration demand

5750 to 8300 ft: runoff patterns change dramatically in the upper Main Westslope Zone and the lower High Ridge Zone:

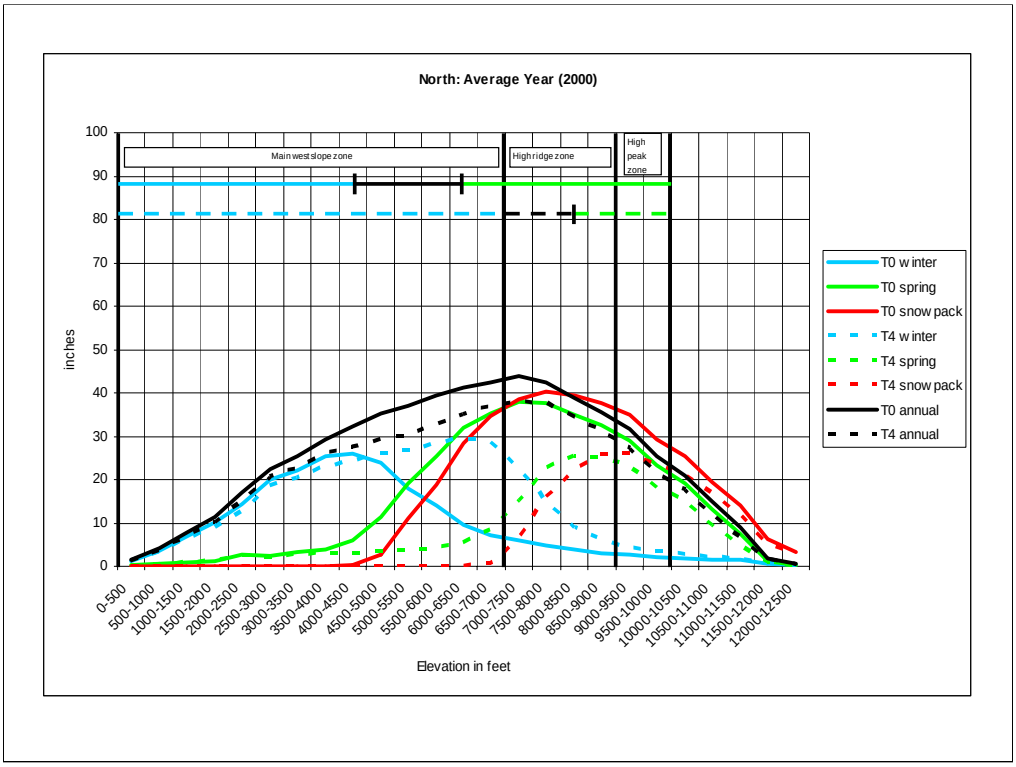
- Winter rainfall RO almost completely replaces spring snowmelt RO
- Spring recessional RO extends to higher elevations and decreases in magnitude
- The potential for summer season baseflows decreases dramatically
- Total RO decreases notably
- The rain-on-snow event elevation interval shifts 2000 ft higher;
    - from the upper Main Westslope Zone
    - to the upper half of the High Ridge Zone

8300 to 9500 ft: runoff patterns change significantly in the upper High Ridge Zone and the lower half of the High Peak Zone:

- Spring snowmelt RO substantially decreases
- Winter snowmelt RO increases and is a larger proportion of total RO
- Total RO remains essentially unchanged
- Substantially reduced snowpack water content and significantly decreased spring snowmelt RO implies a much longer summer baseflow season and a significantly decreases potential for summer season baseflows

9500 to 10,000 ft: runoff patterns change modestly in the upper half of the High Peak Zone:

- Spring snowmelt RO somewhat decreases
- Winter snowmelt RO somewhat increases
- Total RO remains unchanged




North-Sierra Nevada Region: Average Wateryear:

1) Summary of Changes:

Below about 4000 ft, conditions associated with 4dC warming do not result in any significant hydrologic changes. However major hydrologic changes occur between about 4000 and 7500 ft. In this elevation interval, the winter rainfall RO replaces the spring snowmelt RO as the dominant runoff process. Also in this elevation interval, spring recessional RO are significantly reduced as is the potential for summer baseflows. Modeled April 1st snowpack moves to higher elevations and is significantly reduced in water content. Net snowpack loss decreases significantly in magnitude and the elevation interval of occurrence is lessened, moving to the highest elevation interval of the North-Study Region (9000-10,000 ft). Between 7500 and 10,000 ft spring snowmelt RO remains the dominant runoff process however there is a significant increase in winter snowmelt RO below 9000 ft and decrease in spring snowmelt RO throughout. Decreases in modeled annual RO occurs between 2000 and 10,000 ft.

April 1st snowpack regime:

- Shifts 2000 ft higher and decreases significantly in water content, due to increased elevations of rainfall storms and advanced-season snowmelt
- Shifts;
    - from the upper half of the Main Westslope Zone and above
    - to the upper half of the High Ridge Zone and above
- Reduced water content implies that the completion of snowpack melt will occur at an earlier date and the summer baseflow season will be longer in the upper half of the Main Westslope Zone and above

0 to 4500 ft: runoff patterns change slightly in the lower half of the Main Westslope Zone:

- Winter rainfall RO slightly decreases due to increased evapotranspiration demand
- Total RO decreases slightly due to increased evapotranspiration demand

4500 to 7500 ft: runoff patterns change dramatically in the upper half of the Main Westslope Zone and the very lowest portion of the High Ridge Zone:

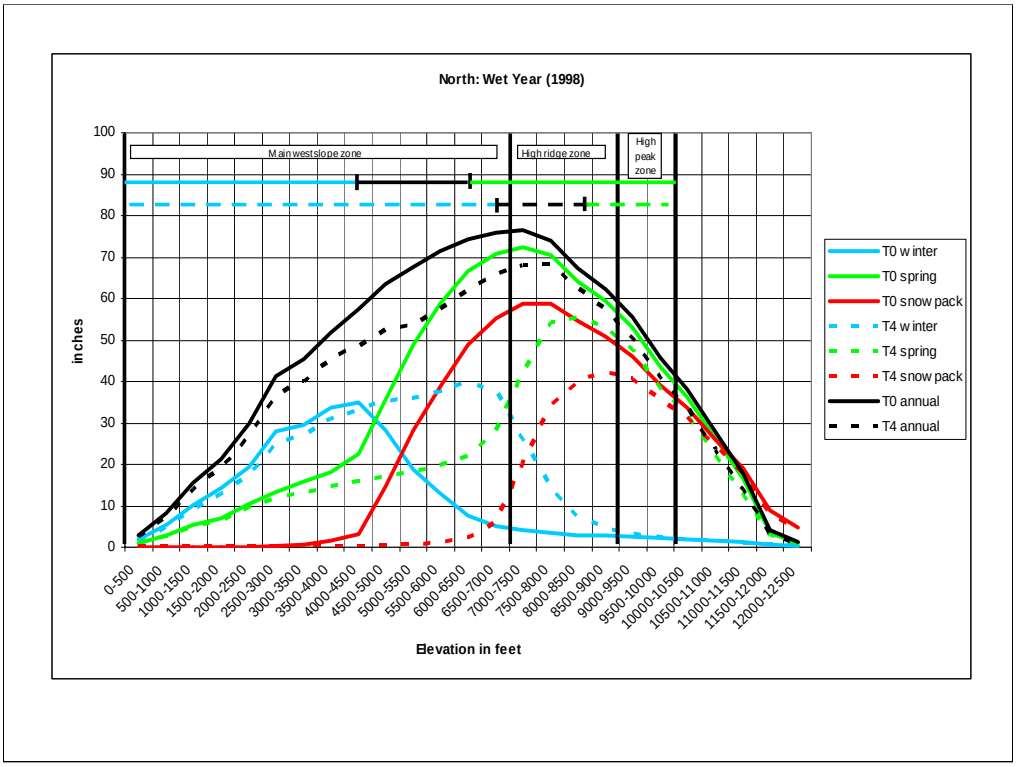
- Winter rainfall RO almost completely replaces spring snowmelt RO
- Spring recessional RO extends to higher elevations and decreases in magnitude
- Dramatically reduced snowpack water content and significantly decreased spring season RO implies a much longer summer baseflow season and dramatically decreased potential for summer season baseflows
- Total RO decreases significantly
- The rain-on-snow event elevation interval shifts 2200 ft higher;
    - from the upper portion of the Main Westslope Zone
    - to the High Ridge Zone

7500 to 9000 ft: runoff patterns change significantly in the upper High Ridge Zone:

- Spring snowmelt RO substantially decreases
- Winter snowmelt RO increases substantially and is a larger proportion of total RO
- Total RO decreases notably
- Significantly reduced snowpack water content and significantly decreased spring season RO implies a much longer summer baseflow season and significantly decreased potential for summer season baseflows

9000 to 10,000 ft: runoff patterns change modestly in the High Peak Zone:

- Spring snowmelt RO somewhat decreases
- Winter snowmelt RO somewhat increases




North-Sierra Nevada Region: Wet Wateryear:

1) Summary of Changes:

Below about 4500 ft, conditions associated with 4dC warming do not result in any significant hydrologic changes but there is some decrease in spring recessional RO in the upper 1500 ft of this elevation interval. However major hydrologic changes occur between 4500 and 7000 ft. In this elevation interval, winter rainfall RO replaces spring snowmelt RO as the dominant runoff process. Also in this elevation interval, spring recessional RO are significantly reduced, as is the potential for summer season baseflows. Modeled April 1st snowpack moves to higher elevations and is significantly reduced in water content, particularly below 9000 ft. Net snowpack loss remain essentially unchanged. Between about 7000 and 10,000 ft spring snowmelt RO remains the dominant runoff process however there is a significant increase in winter snowmelt RO below 8500 ft and decrease in spring snowmelt RO below 9000 ft. Decreases in modeled total RO occur between 3000 and 10,000 ft.

2) Runoff Domain Changes:

The index snowline dynamic elevation increases about 2300 ft to 6900 ft, the runoff transition domain increases about 2000-3000 ft to 6750-8250 ft, and the elevation of the rain-on-snow event interval increases about 2300 ft to about 5900-7900 ft. In the 4250-6750 ft interval, the runoff transition domain and the spring snowmelt RO domain change to the winter rainfall RO domain. In the 6750-8250 ft interval, the spring snowmelt RO domain changes to the runoff transition domain. There is no change in net snowpack loss, it remains absent. There is a decrease in modeled annual RO between 3000 and 10,000 ft with losses greatest (about 20%) in the 4500-7000 ft interval.

April 1st snowpack regime:

- Shifts 2000 ft higher and decreases significantly in water content, due to increased elevations of rainfall storms and advanced-season snowmelt
- Shifts;
    - from the upper half of the Main Westslope Zone and above
    - to the High Ridge Zone and above
- Reduced water content implies that completion of snowpack melt will occur at an earlier date and the summer baseflow season will be longer in the upper half of the Main Westslope Zone and above

0 to 4250 ft: runoff patterns change slightly in the lower half of the Main Westslope Zone:

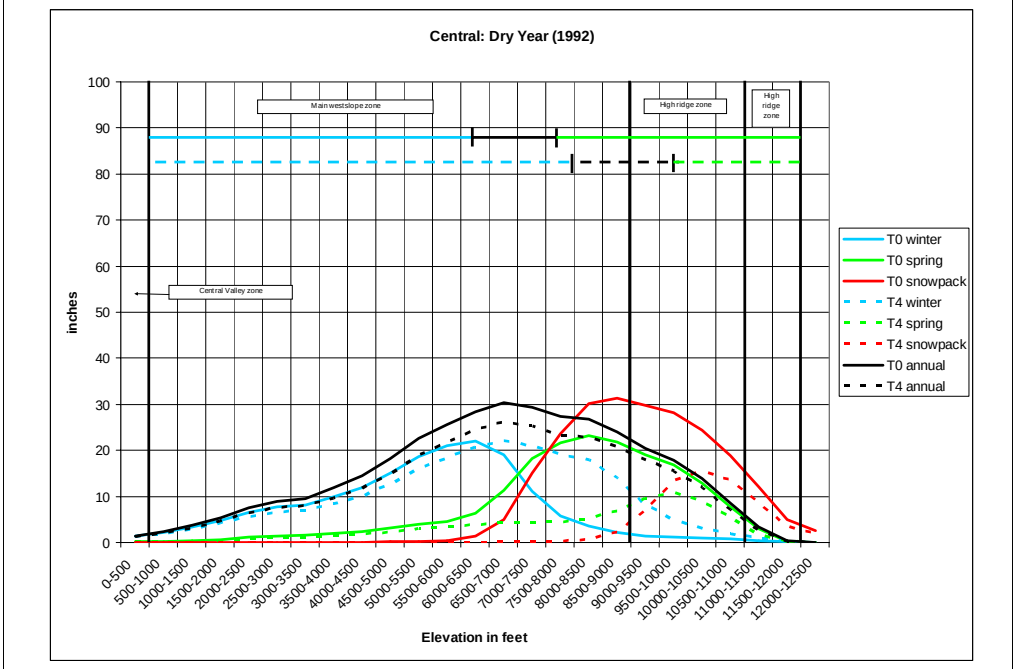
- Winter rainfall RO slightly decreases due to increased evapotranspiration demand
- Spring recessional RO somewhat decreases above 3000 ft
- Total RO decreaseslightlyty due to increased evapotranspiration demand

4250 to 7000 ft: runoff patterns change dramatically in the upper half of the Main Westslope Zone:

- Winter rainfall RO becomes dominant over spring snowmelt RO changing from dramatically spring snowmelt RO dominated to somewhat dominated by winter rainfall RO
- Spring recessional RO extends to higher elevations and decreases in magnitude
- Total RO decreases dramatically
- Greatly reduced snowpack water content and significantly decreased spring season RO implies a much longer summer baseflow season and significantly decreased potential for summer season baseflows
- The rain-on-snow event elevation interval shifts 2400 ft higher;
    - from the middle Main Westslope Zone
    - to the upper most Main Westslope Zone and the lower High Ridge Zone

7000 to 8500 ft: runoff patterns change significantly in the High Ridge Zone:

- Spring snowmelt RO substantially decreases
- Winter snowmelt RO increases significantly and is a larger proportion of total RO




Central-Sierra Nevada Region: Dry Wateryear:

1) Summary of Changes:

Below about 6500 ft, conditions associated with 4dC warming do not result in any significant hydrologic changes. However major hydrologic changes occur between 6500 and 9200 ft. In this elevation interval, winter rainfall RO replaces spring snowmelt RO as the dominant runoff process. Also in this elevation interval, spring recessional RO significantly reduced, as is the potential for summer season baseflows. Modeled April 1st snowpack moves to higher elevations and is significantly reduced in water content. Net snowpack loss decreases significantly in magnitude and elevation interval of occurrence is lessened, moving to the highest elevation interval of the Central-Study Region (9500-12,000 ft). Between 9200 and 12,000 ft spring snowmelt RO remains the dominant runoff process however there is a significant increase in winter snowmelt RO below 10,000 ft and a decrease in spring snowmelt RO below 10,500 ft. Decreases in modeled annual RO occur between 2000 and 10,000 ft.

2) Runoff Domain Changes:

The index snowline dynamic elevation increases about 2200 ft to 9200 ft, the runoff transition domain increases about 2000 ft to 8000-9750 ft, and the elevation of the rain-on-snow event interval increases about 2200 ft to about 7200-10,200 ft. In the 6250-8000 ft interval, the runoff transition domain and the spring snowmelt RO domain change to the winter rainfall RO domain. In the 8000-9750 ft interval, the spring snowmelt RO domain changes to the runoff transition domain. The lower elevation limit of net snowpack loss increases about 2300 ft to about 9500 ft with a decrease in average loss rate from about 18% to about 12% of the pack. The overall reduction in net snowpack loss occurs because if the greatly lessened elevation interval of occurrence with warming temperatures. There is a decrease in modeled total RO between 2000 and 10,000 ft with the greatest decreases (about 15%) in the 5500-8500 ft interval.

April 1st snowpack regime:

- Shifts 2500 ft higher and decreases significantly in water content due to increased elevations of rainfall storms and advanced-season snowmelt
- Shifts;
    - from the highest portion of the Main Westslope Zone and the High Ridge Zone
    - to the High Ridge Zone
- Reduced water content implies that the completion of snowpack melt will occur at an earlier date and the summer baseflow season will be longer in the upper Main Westslope Zone and above

500 to 6500 ft: runoff patterns change slightly in the lower and middle Main Westslope Zone:

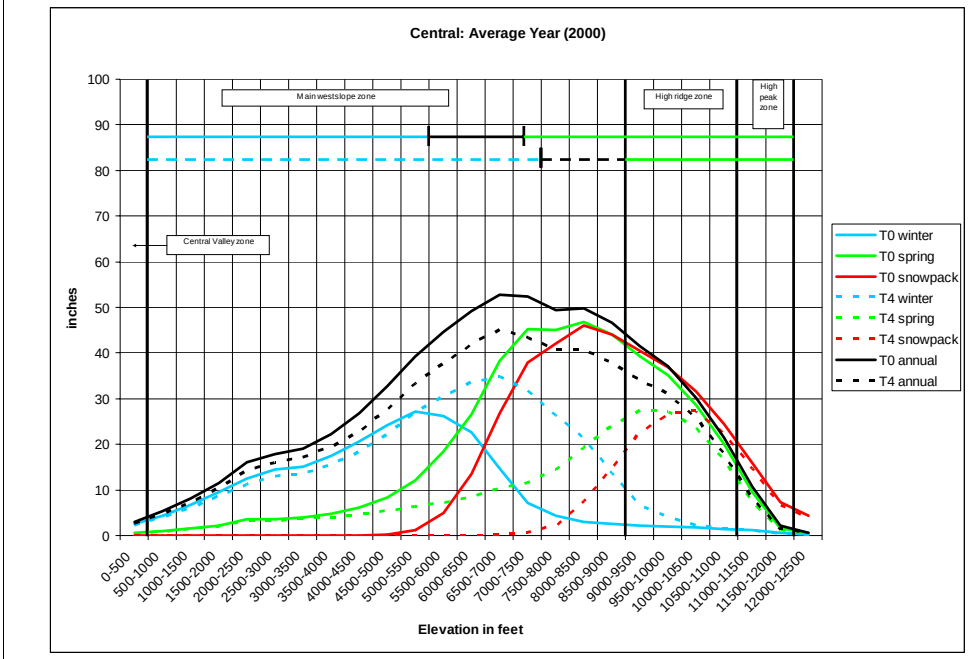
- Winter rainfall RO is slightly decreased due to increased losses by evapotranspiration demand
- Total RO decreases slightly due to increased evapotranspiration demand

6500 to 9200 ft: runoff patterns change dramatically in the upper Main Westslope Zone:

- Winter rainfall RO almost completely replaces spring snowmelt RO
- Spring recessional RO extends to higher elevations and decreases in magnitude
- Dramatically reduced snowpack water content and significantly decreased spring season RO implies a substantially longer summer baseflow season and significantly decreased potential for summer season baseflows
- Total RO decreases notably
- The rain-on-snow event elevation interval shifts 2200 ft higher;
    - from the upper-mid portion of the Main Westslope Zone
    - to the upper Main Westslope Zone and the lower High Ridge Zone

9200 to 10,500 ft: runoff patterns change significantly in the High Ridge Zone:

- Spring snowmelt RO substantially decrease




Central-Sierra Nevada Region: Average Wateryear:

1) Summary of Changes:

Below about 5500 ft, conditions associated with 4dC warming do not result in any significant hydrologic changes. However major hydrologic changes occur between 5500 and 8300 ft. In this elevation interval, winter rainfall RO replaces spring snowmelt RO as the dominant runoff process. Also in this elevation interval, spring recessional RO are significantly reduced, as is the potential for summer season baseflows. Modeled April 1st snowpack moves to higher elevations and is significantly reduced in water content. Net snowpack loss decreases slightly in magnitude while the and elevation interval of occurrence is significantly lessened, moving to the highest elevation interval of the Central-Study Region (9600-12,000 ft). Between 8300 and 12,000 ft spring snowmelt RO remains the dominant runoff process however there is a significant increase in winter snowmelt RO below 9500 ft and a decrease in spring snowmelt RO below 10,500 ft. Decrease in modeled total RO occurs between 3000 and 10,500 ft.

2) Runoff Domain Changes:

The index snowline dynamic elevation increases about 2200 ft to 8300 ft, the runoff transition domain increases about 2000 ft to 7500-9000 ft, and the elevation of the rain-on-snow event interval increases about 2200 ft to about 7300-9300 ft. In the 5500-7500 ft interval, the runoff transition domain and the spring snowmelt RO domain change to the winter rainfall RO domain. In the 7500-9000 ft interval, the spring snowmelt RO domain changes to the runoff transition domain. The lower elevation limit of net snowpack loss increases about 1000 ft to about 9750 ft with no notable change in overall pack losses. There is a decrease in modeled total RO between 3000 and 10,500 ft with the greatest decreases (about 18%) in the 6000-9500 ft interval.

April 1st snowpack regime:

- Shifts 2200 ft higher and decreases significantly in water content due to increased elevations of rainfall storms and advanced-season snowmelt
- Shifts;
    - from the upper half of the Main Westslope Zone and the High Ridge Zone
    - to the High Ridge Zone
- Reduced water content implies that the completion of snowpack melt will occur at an earlier date and the summer baseflow season will be longer in the upper half of the Main Westslope Zone and the lower half of the High Ridge Zone

500 to 5250 ft: runoff patterns change slightly in the lower half of the Main Westslope Zone:

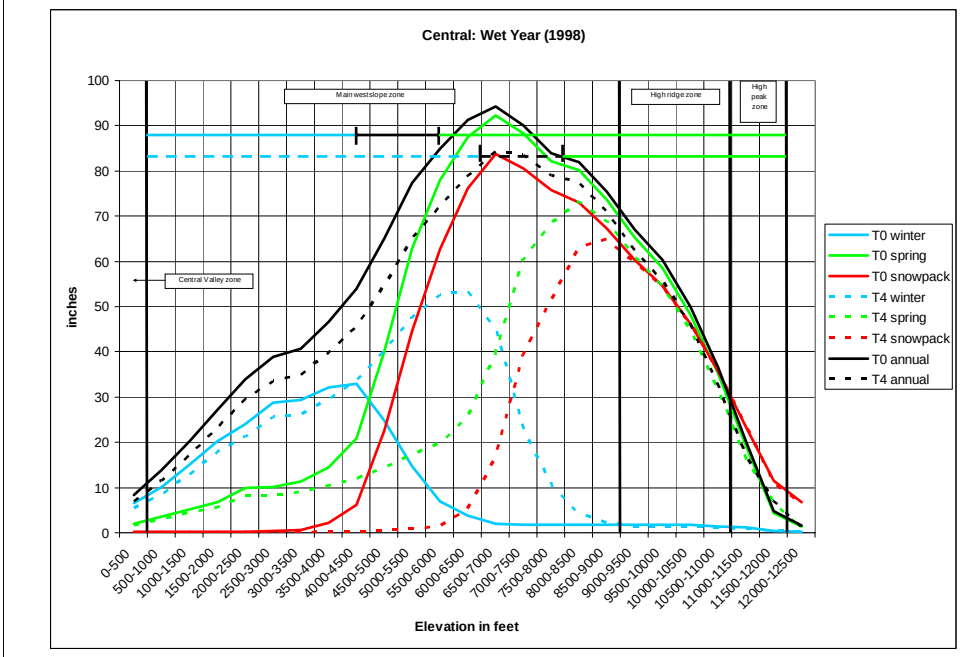
- Winter rainfall RO slightly decreases due to increased evapotranspiration demand
- Spring recessional RO decreases notably above 4500 ft
- Total RO decreases slightly due to increased evapotranspiration demand

5250 to 8250 ft: runoff patterns change dramatically in the upper half of the Main Westslope Zone:

- Winter rainfall RO almost completely replaces spring snowmelt RO
- Spring recessional RO extends to higher elevations and decreases in magnitude
- Dramatically reduced snowpack water content and significantly decreased spring season RO implies a much longer summer baseflow season and dramatically decreased potential for summer season baseflows
- Total RO deceases significantly
- The rain-on-snow event elevation interval shifts 2300 ft higher;
    - from the middle Main Westslope Zone
    - to the upper most portion of the Main Westslope Zone

8250 to 10,000 ft: runoff patterns change significantly in the lower half of the High Ridge Zone:

- Spring snowmelt RO substantially decreases




Central-Sierra Nevada Region: Wet Wateryear:

1) Summary of Changes:

Below about 4500 ft, conditions associated with 4dC warming do not result in any significant hydrologic changes but there is some decrease in spring recessional RO in the upper 1500 ft of this elevation interval. However major hydrologic changes occur between 4500 and 7000 ft. In this elevation interval, winter rainfall RO replaces spring snowmelt RO as the dominant runoff process. Also in this elevation interval, spring recessional RO are significantly reduced, as is the potential for summer season baseflows. Below 9000 ft, modeled April 1st snowpack moves to higher elevations and is significantly reduced in water content. Above 9000 ft, modeled April 1st snowpack remains unchanged. Net snowpack loss remain essentially unchanged. Between 7000 and 10,000 ft spring snowmelt RO remains the dominant runoff process however there is a significant increase in winter snowmelt RO below 8500 ft and a decrease in spring snowmelt RO below 9000 ft. Decrease in modeled total RO occurs between 1500 and 10,000 ft.

2) Runoff Domain Changes:

The index snowline dynamic elevation increases about 2300 ft to 6800 ft, the runoff transition domain increases about 2250 ft to 6500-8000 ft, and the elevation of the rain-on-snow event interval increases about 2300 ft to about 5800-7800 ft. In the 4250-6500 ft interval, the runoff transition domain and the spring snowmelt RO domain change to the winter rainfall RO domain. In the 6500-8000 ft interval, the spring snowmelt RO domain changes to the runoff transition domain. The lower elevation limit of net snowpack loss stays at about the same elevation, and the magnitudes of net snowpack loss remain essentially unchanged. There is a decrease in modeled total RO between 1500 and 10,000 ft with losses greatest (about 14%) in the 5500-7500 ft interval.

April 1st snowpack regime:

- Shifts 2000 ft higher and decreases significantly in water content, due to increased elevations of rainfall storms and advanced-season snowmelt
- Shifts;
    - from the upper half of the Main Westslope Zone and the High Ridge Zone
    - to the upper portion of the Main Westslope Zone and the High Ridge Zone
- Reduced water content implies that completion of snowpack melt will occur at an earlier date and the summer baseflow season will be longer in the upper half of the Main Westslope Zone

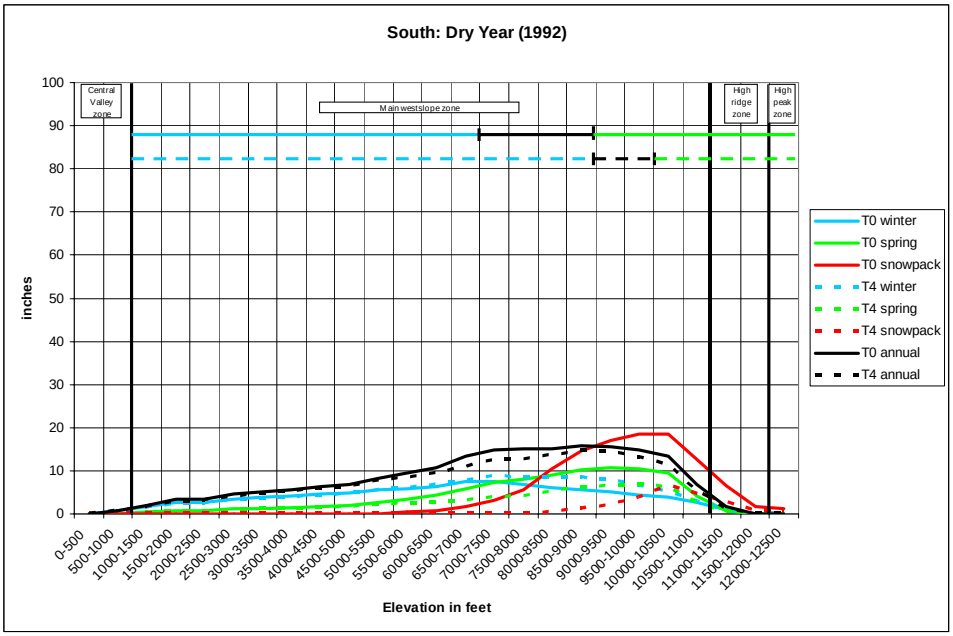
500 to 4250 ft: runoff patterns change slightly in the lower half of the Main Westslope Zone:

- Winter rainfall RO slightly decreases due to increased evapotranspiration demand
- Spring recessional RO somewhat decreases above 2500 ft
- Total RO decreases significantly due to increased evapotranspiration demand

4250 to 6700 ft: runoff patterns change dramatically in the middle portion of the Main Westslope Zone:

- Winter rainfall RO becomes dominant over spring snowmelt RO changing from dramatically spring snowmelt RO dominated to substantially dominated by winter rainfall RO
- Spring recessional RO extends to higher elevations and decreases in magnitude
- Total RO decreases dramatically
- Greatly reduced snowpack water content and significantly decreased spring season RO implies a much longer summer baseflow season and significantly decreased potential for summer season baseflows
- The rain-on-snow event elevation interval shifts 2300 ft higher;
    - from the lower middle Main Westslope Zone
    - to the middle upper Main Westslope Zone

6700 to 8500 ft: runoff patterns change significantly in the upper portion of the Main Westslope Zone:




South-Sierra Nevada Region:: Dry Wateryear:

1) Summary of Changes:

Below about 7250 ft, conditions associated with 4dC warming do not result in any significant hydrologic changes but there is some decreases in spring recessional RO in the higher 1200 ft. However moderate hydrologic changes occur between 7250 and 9500 ft. In this elevation interval, winter rainfall RO replaces spring snowmelt RO as the dominant runoff process. Also in this elevation interval, spring recessional RO is notably reduced, as is the potential for summer season baseflows. Modeled April 1st snowpack moves to higher elevations and is greatly reduced in water content. Net snowpack loss decreases significantly in magnitude and elevation interval of occurrence is lessened, moving to the highest elevation interval of the South-Study Region (10,250-12,500 ft). Between 9500 and 12,500 ft spring snowmelt RO remains the dominant runoff process however there is a modest increase in winter snowmelt RO below 10,500 ft and a decrease in spring snowmelt RO below 11,000 ft. Decreases in modeled annual RO occur between 6500 and 10,000 ft.

2) Runoff Domain Changes:

The index snowline dynamic elevation increases about 2450 ft to 9750 ft, the runoff transition domain increases about 1000-2000 ft to 9000-10,000 ft, and the elevation of the rain-on-snow event interval increases about 2450 ft to about 8750-10,750 ft. In the 7000-9000 ft interval, the runoff transition domain changes to the winter rainfall RO domain. In the 9000-10,000 ft interval, the spring snowmelt RO domain changes to the runoff transition domain. The lower elevation limit of net snowpack loss increases about 2250 ft to about 10,250 ft, and increases in average loss rates from about 43% to about 67% of the pack. The overall reduction in net snowpack loss occurs because of the greatly lessened elevation interval of occurrence with warming temperatures. There is a decrease in modeled total RO between 6500 and 10,000 ft with the greatest decreases (about 15%) in the 6750-8000 ft interval.

April 1st snowpack regime:

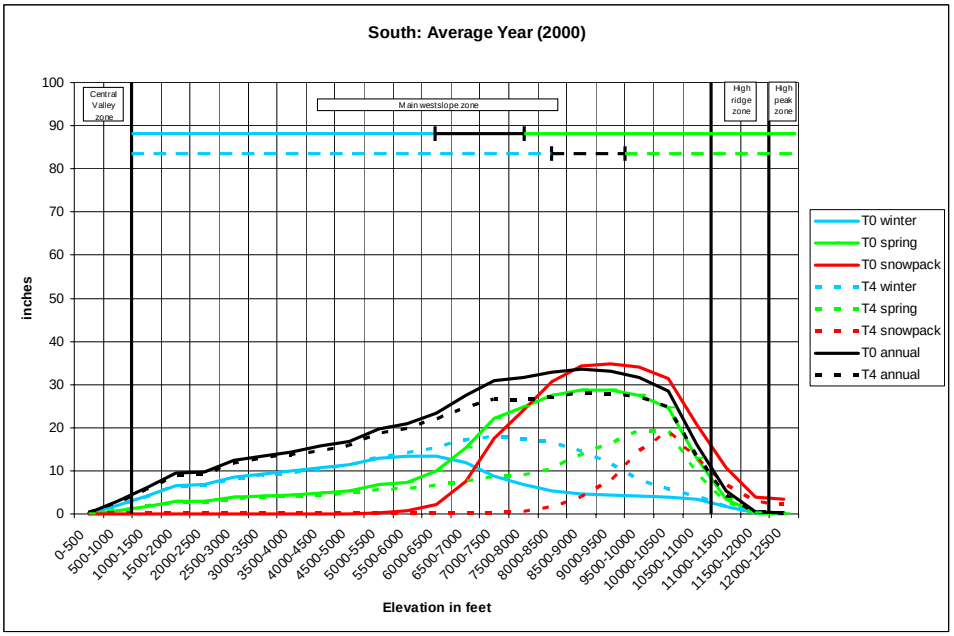
- Shifts about 2000 ft higher and decreases significantly in water content, due to increased elevations of rainfall storms and advanced-season snowmelt
- Shifts;
    - from the upper portion of the Main Westslope Zone
    - to the highest portion of the Main Westslope Zone
- Reduced water content implies that the completion of snowpack melt will occur at an earlier date and the summer baseflow season will be longer in the upper Main Westslope Zone and above

1000 to 6750 ft: runoff patterns change slightly in the lower and middle Main Westslope Zone:

- Winter rainfall RO is slightly decreased due to increased losses by evapotranspiration demand
- Spring recessional RO decreased slightly above 6000 ft
- Total RO decreases slightly due to increased evapotranspiration demand

6750 to 9500 ft: runoff patterns change dramatically in the upper Main Westslope Zone:

- Winter rainfall RO becomes the dominant process and spring snowmelt RO decreases notably
- Spring recessional RO extends to higher elevations and decreases in magnitude
- The potential for summer season baseflows decreases substantially
- Total RO decreases slightly
- Dramatically reduced snowpack water content and significantly decreased spring season RO implies a much longer summer baseflow season and significantly decreased potential for summer season baseflows
- The rain-on-snow event elevation interval shifts 2300 ft higher;
    - from the middle Main Westslope Zone
    - to the upper Main Westslope Zone




South-Sierra Nevada Region: Average Wateryear:

1) Summary of Changes:

Below about 6000 ft, conditions associated with 4dC warming do not result in any significant hydrologic changes. However major hydrologic changes occur between 6000 and 8750 ft. In this elevation interval, winter rainfall RO replaces spring snowmelt RO as the dominant runoff process. Also in this elevation interval, spring recessional RO are significantly reduced, as is the potential for summer season baseflows. Modeled April 1st snowpack moves to higher elevations and is significantly reduced in water content. Net snowpack loss decreases significantly in magnitude while the and elevation interval of occurrence is significantly lessened, moving to the highest elevation interval of the South-Study Region (10,500-12,500 ft). Between about 8750 and 12,000 ft spring snowmelt RO remains the dominant runoff process however there is a significant increase in winter snowmelt RO below 10,500 ft and a decrease in spring snowmelt RO throughout. Decrease in modeled total RO occurs between 6750 and 10,250 ft.

2) Runoff Domain Changes:

The index snowline dynamic elevation increases about 2300 ft to 8800 ft, the runoff transition domain increases about 2000 ft to 8250-9500 ft, and the elevation of the rain-on-snow event interval increases about 2300 ft to about 7800-9800 ft. In the 6250-8250 ft interval, the runoff transition domain and spring snowmelt RO domain change to the winter rainfall RO domain. In the 8250-9500 ft interval, the spring snowmelt RO domain changes to the runoff transition domain. The lower elevation limit of net snowpack loss increases about 3000 ft to about 10,750 ft, with increases net snowpack loss magnitude from 17% to 67% of the pack. The overall reduction of net snowpack loss occurs because of the greatly lessened elevation interval of occurrence with warming temperatures. There is a decrease in modeled total RO between 6750 and 10,250 ft with the greatest decreases (about 16%) in the 6700-10,000 ft interval.

April 1st snowpack regime:

- Shifts 2500 ft higher and decreases significantly in water content due to increased elevations of rainfall storms and advanced-season snowmelt
- Shifts;
    - from the upper half of the Main Westslope Zone
    - to the upper-most portion of the Main Westslope Zone
- Reduced water content implies that the completion of snowpack melt will occur at an earlier date and the summer baseflow season will be longer in the upper half of the Main Westslope Zone and the lower half of the High Ridge Zone

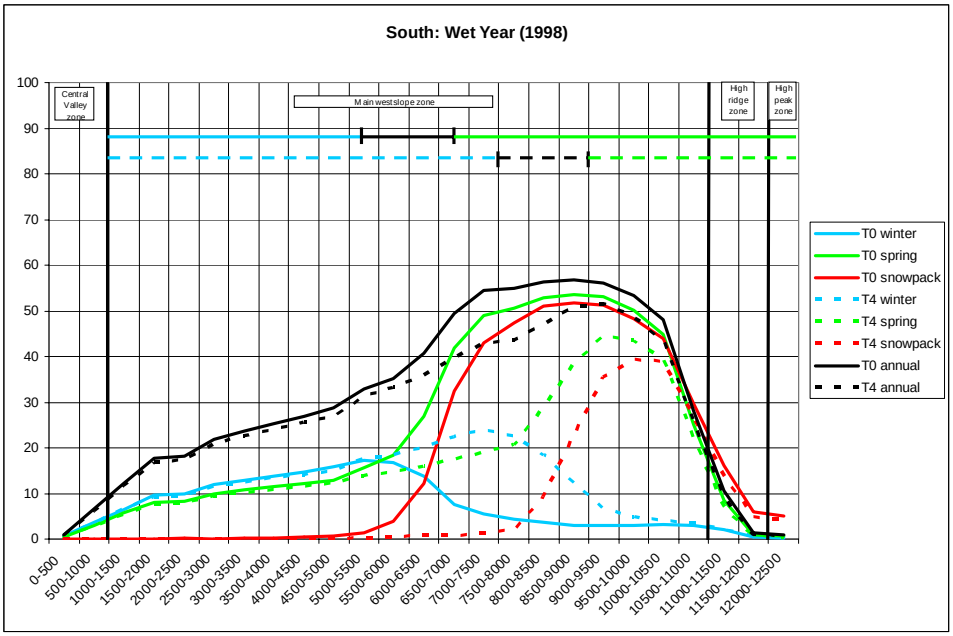
1000 to 6000 ft: runoff patterns change very slightly in the lower half of the Main Westslope Zone:

- Winter rainfall RO remains essentially unchanged
- Spring recessional RO decreases slightly above 5500 ft
- Total RO remains essentially unchanged

6000 to 8750 ft: runoff patterns change dramatically in the upper half of the Main Westslope Zone:

- Winter rainfall RO substantially replaces spring snowmelt RO as the dominant process
- Spring recessional RO extends to higher elevations and decreases in magnitude
- Dramatically reduced snowpack water content and significantly decreased spring season RO implies a much longer summer baseflow season and dramatically decreased potential for summer season baseflows
- Total RO deceases significantly
- The rain-on-snow event elevation interval shifts 2300 ft higher;
    - from the middle Main Westslope Zone
    - to the upper-middle portion of the Main Westslope Zone

8750 to 10,500 ft: runoff patterns change significantly in the upper-most portion of the Main Westslope Zone:




South-Sierra Nevada Region: Wet Wateryear:

**1) Summary of Changes:**

Below about 5500 ft, conditions associated with 4dC warming do not result in any significant hydrologic changes but there is a small decrease in *spring recessional RO* in the upper 500 ft of that interval.. However major hydrologic changes occur between 5500 and 7800 ft. In this elevation interval, *winter rainfall RO* replaces *spring snowmelt RO* as the dominant runoff process. Also in this elevation interval, *spring recessional RO* are significantly reduced, as is the potential for summer season baseflows. *Modeled April 1st snowpack* moves to higher elevations and is significantly reduced in water content. There is essentially no change *Net snowpack loss*, neither in magnitude, elevation interval of occurrence, and overall amount. Between 7800 and 12,500 ft *spring snowmelt RO* remains the dominant runoff process however there is a significant increase in *winter snowmelt RO* below 9500 ft and a decrease in *spring snowmelt RO* below 10,500 ft. Decrease in *modeled total RO* occurs between 6000 and 10,250 ft.

**2) Runoff Domain Changes:**

The *index snowline dynamic elevation* increases about 2300 ft to 7800 ft, the *transition runoff domain* increases about 2250 ft to 7500-9000 ft, and the elevation of the rain-on-snow event interval increases about 2300 ft to about 6800-8800 ft. In the 5250-7500 ft interval, the *runoff transition domain* and *spring snowmelt RO domain* change to the *winter rainfall RO domain*. In the 7500-9000 ft interval, the *spring snowmelt RO domain* changes to the *runoff transition domain*. The lower elevation limit of *net snowpack loss* remains at about 10,300 ft along with little change in *net snowpack loss* (remains at 0-90%). There is a decrease in *modeled total RO* between 6000 and 10,250 ft with the greatest decreases (about 21%) in the 6750-8500 ft interval.

**April 1st snowpack regime:**

- Shifts 2000 ft higher and decreases significantly in water content, due to increased elevations of rainfall storms and advanced-season snowmelt
- Shifts;
    - from the upper half of the Main Westslope Zone
    - to the upper-most portion of the Main Westslope Zone
- Reduced water content implies that completion of snowpack melt will occur at an earlier date and the summer baseflow season will be longer in the upper half of the Main Westslope Zone

**1000 to 5500 ft:** runoff patterns change slightly in the lower half of the Main Westslope Zone:

- *Winter rainfall RO* slightly decreases due to increased evapotranspiration demand
- *Spring recessional RO* somewhat decreases above 5000 ft
- *Total RO* decreases slightly due to increased evapotranspiration demand

**5500 to 7700 ft:** runoff patterns change dramatically in the middle portion of the Main Westslope Zone:

- *Winter rainfall RO* becomes dominant over *spring snowmelt RO* changing from dramatically *spring snowmelt RO* dominated to somewhat dominated by *winter rainfall RO*
- *Spring recessional RO* extends to higher elevations and decreases in magnitude
- *Total RO* decreases dramatically
- Greatly reduced snowpack water content and significantly decreased *spring season RO* implies a much longer summer baseflow season and significantly decreased potential for summer season baseflows
- The rain-on-snow event elevation interval shifts 2300 ft higher;
    - from the lower-middle portion of the Main Westslope Zone
    - to the middle-upper portion of the Main Westslope Zone

**7700 to 10,000 ft:** runoff patterns change significantly in the upper portion of the Main Westslope Zone: