Santa Ana River Watershed
Hydrology Projections

February 2, 2012, Fountain Valley, CA

Water Resources Planning and Operations Support Group
Technical Service Center, Denver, Colorado
Hydrology Projections Outline

1. Background. Acronyms, definitions, assumptions, and hydrology model overview.

2. How were the hydrologic projections developed for the Santa Ana Watershed? Detailed description of the hydrologic projections development process, specifically streamflow.

3. What analysis was done using the hydrology projections? Detailed description of analysis of change and statistics used.

4. Results. All results are preliminary and draft.

5. Example analysis. Change in runoff using the hydrologic projections website hosted at Lawrence Livermore National Lab (LLNL).

6. Summary

7. Next Steps
1. **Background.** 
   Acronyms, definitions, assumptions, and hydrology model overview.

2. **How were the hydrologic projections developed for the Santa Ana Watershed?** Detailed description of the hydrologic projections development process, specifically streamflow.

3. **What analysis was done using the hydrology projections?** Detailed description of analysis of change and statistics used.

4. **Results.** All results are preliminary and draft.

5. **Example analysis.** Change in runoff using the hydrologic projections website hosted at Lawrence Livermore National Lab (LLNL).

6. **Summary**

7. **Next Steps**

**BACKGROUND**
Acronyms

• VIC – Variable Infiltration Capacity Model. Hydrology model.

• BCSD – Bias Corrected and Spatially Downscaled. Statistical method of developing hydrology model inputs (precipitation and temperature) from global climate model (GCM) runs.

• CMIP-3 – Coupled Model Intercomparison Project, Phase 3. Most current global climate model runs.

• WWCRA – West-Wide Climate Risk Assessments (an activity under Reclamation’s WaterSMART program). First SECURE Water Act report - West-wide effort to develop gridded hydrology.
Definitions

• **Bias** - statistical term meaning a systematic (not random) deviation from the true value.

• **Ensemble** – set of model (e.g., climate or hydrology) runs based on different initial conditions, forcings, and model physics. The result of each model run is called an Ensemble member.

• **Median** - the median is the value that has just as many values above it as below it (50th percentile). Measure of central tendency.

• **Runoff** – for a gridded hydrology model, is the surface flow (surface runoff) or base flow (sub-surface runoff). Total runoff is the sum of surface and sub-surface runoff.

• **Streamflow** – cumulative runoff at a gage location derived by routing water through a channel network.

• **Ensemble Median** – median calculated from all the individual ensemble members.

• **Re-sampling** – replicating sample data based on a specified pattern.
Assumptions

• 10-year base or reference hydrology period, water years 1990-1999. 1990s.

• Three (3) future look ahead periods:
  – water years 2020-2029. 2020s.
  – water years 2050-2059. 2050s.
  – water years 2070-2079. 2070s.
Background Information – Hydrology Model

- Gridded macro-scale (grid size, > 1 km) hydrology model, VIC (Variable Infiltration Capacity)
- VIC model version 4.0.7
Hydrologic Modeling – VIC Setup, 2 Steps

1. Land Surface Simulation
   - simulate runoff (and other fluxes) at each grid cell

2. Streamflow Routing
   - transport runoff from grid cell to outlet
What happens next - Step 1?

STEP 1

• For each grid cell VIC simulates daily fluxes:
  – surface runoff
  – baseflow
  – evapotranspiration
  – etc.
What happens next – Step 2?

STEP 2

• Transport runoff (surface runoff and baseflow) - move water from the grid cells through the flow network to the outlet or routing locations of interest
Hydrologic Modeling - VIC

• Calibrated to reproduce monthly to annual runoff in large sub-basins.

• These models have biases.
HOW WERE THE HYDROLOGIC PROJECTIONS DEVELOPED FOR THE SANTA ANA WATERSHED?

1. Background. Acronyms, definitions, assumptions, and hydrology model overview.

2. How were the hydrologic projections developed for the Santa Ana Watershed? Detailed description of the hydrologic projections development process, specifically streamflow.

3. What analysis was done using the hydrology projections? Detailed description of analysis of change and statistics used.

4. Results. All results are preliminary and draft.

5. Example analysis. Change in runoff using the hydrologic projections website hosted at Lawrence Livermore National Lab (LLNL).

6. Summary

7. Next Steps
How were the hydrologic projections developed for the Santa Ana Watershed?

• Steps in the hydrology projections development process.
  1. Development of VIC input datasets from the BCSD-CMIP-3 archive
  2. Identification of key locations in the Basin, sub-basins
  3. Sub-basin delineation
  4. Developing the VIC routing models
  5. Flow routing using WWCRA gridded runoff
Step 1: Development of VIC input datasets from the BCSD-CMIP-3 archive

1. Daily precipitation (PRCP), minimum temperature (TMIN), maximum temperature (TMAX), and wind speed (WIND) – daily forcings


3. For each grid cell daily forcing starting on January 1, 1950, and going out to December 31, 2099 developed based on re-sampling of BCSD-CMIP-3 projections from historical daily forcings data (Step 2, above).
Step 2: Identification of key locations in the Basin
<table>
<thead>
<tr>
<th>ID</th>
<th>Lat</th>
<th>Lon</th>
<th>Site Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33.675020160</td>
<td>-117.835611000</td>
<td>Peters_Canyon_Wash_Tustin_Gage</td>
</tr>
<tr>
<td>2</td>
<td>33.683909460</td>
<td>-117.745330710</td>
<td>Marshburn_Channel_Gage</td>
</tr>
<tr>
<td>3</td>
<td>33.681686820</td>
<td>-117.809499150</td>
<td>San_Diego_Creek_Myford_Rd_Gage</td>
</tr>
<tr>
<td>4</td>
<td>33.725442191</td>
<td>-117.802408768</td>
<td>El_Modina-Irvine_Channel_Gage</td>
</tr>
<tr>
<td>5</td>
<td>33.693809460</td>
<td>-117.823037908</td>
<td>Peters_Canyon_Wash_Irvine_Gage</td>
</tr>
<tr>
<td>6</td>
<td>33.672798000</td>
<td>-117.835888800</td>
<td>San_Diego_Creek_Lane_Rd_Gage</td>
</tr>
<tr>
<td>7</td>
<td>33.655576290</td>
<td>-117.845611300</td>
<td>San_Diego_Creek_Campus_Dr_Gage</td>
</tr>
<tr>
<td>8</td>
<td>33.885294816</td>
<td>-117.651816486</td>
<td>Santa_Ana_River_Prado_Dam_Gage</td>
</tr>
<tr>
<td>9</td>
<td>33.872738742</td>
<td>-117.670852174</td>
<td>Santa_Ana_River_County_Line_Gage</td>
</tr>
<tr>
<td>10</td>
<td>33.856404490</td>
<td>-117.790611220</td>
<td>Santa_Ana_River_Imperial_Highway_Gage</td>
</tr>
<tr>
<td>11</td>
<td>33.855848910</td>
<td>-117.797555880</td>
<td>Santa_Ana_River_AB_SPRD_Imperial_Highway_Gage</td>
</tr>
<tr>
<td>12</td>
<td>33.856404440</td>
<td>-117.800893000</td>
<td>Santa_Ana_River_SPRD_Imperial_Highway_Gage</td>
</tr>
<tr>
<td>13</td>
<td>33.888903530</td>
<td>-117.845335820</td>
<td>Carbon_Creek_Olinda_Gage</td>
</tr>
<tr>
<td>14</td>
<td>33.889459080</td>
<td>-117.845335830</td>
<td>Carbon_Creek_Yorba_Linda_Gage</td>
</tr>
<tr>
<td>15</td>
<td>33.818812586</td>
<td>-117.873013779</td>
<td>Santa_Ana_River_Ball_Rd_Gage</td>
</tr>
<tr>
<td>16</td>
<td>33.802238450</td>
<td>-117.878390750</td>
<td>Santa_Ana_River_Katella_Ave_Gage</td>
</tr>
<tr>
<td>17</td>
<td>33.822794190</td>
<td>-117.776721310</td>
<td>Santiago_Creek_Villa_Park_Gage</td>
</tr>
<tr>
<td>18</td>
<td>33.822794190</td>
<td>-117.776721310</td>
<td>Santiago_Creek_Div_Villa_Park_Gage</td>
</tr>
<tr>
<td>19</td>
<td>33.777261477</td>
<td>-117.878057039</td>
<td>Santiago_Creek_Santa_Ana_Gage</td>
</tr>
<tr>
<td>20</td>
<td>33.752045602</td>
<td>-117.906379262</td>
<td>Santa_Ana_River_Santa_Ana_Gage</td>
</tr>
<tr>
<td>21</td>
<td>33.672033347</td>
<td>-117.943733939</td>
<td>Santa_Ana_River_Adams_St_Gage</td>
</tr>
<tr>
<td>22</td>
<td>33.887792060</td>
<td>-117.926449600</td>
<td>Brea_Channel_Brea_Dam_Gage</td>
</tr>
<tr>
<td>23</td>
<td>33.873625670</td>
<td>-117.925893710</td>
<td>Brea_Channel_Fullerton_Gage</td>
</tr>
<tr>
<td>24</td>
<td>33.895847650</td>
<td>-117.886170600</td>
<td>Fullerton_Channel_Fullerton_Dam_Gage</td>
</tr>
<tr>
<td>25</td>
<td>33.872875108</td>
<td>-117.902127395</td>
<td>Fullerton_Channel_Fullerton_Gage</td>
</tr>
<tr>
<td>26</td>
<td>33.860696271</td>
<td>-117.929366516</td>
<td>Fullerton_Channel_Richman_Ave_Gage</td>
</tr>
<tr>
<td>27</td>
<td>33.810571570</td>
<td>-118.075342080</td>
<td>Coyote_Creek_Los_Alamitos_Gage</td>
</tr>
<tr>
<td>28</td>
<td>34.259256110</td>
<td>-117.330684440</td>
<td>Devils_Canyon</td>
</tr>
<tr>
<td>29</td>
<td>33.968611110</td>
<td>-117.447500000</td>
<td>Santa_Ana_River_AT_Metropolitan_Water_District_Crossing_NR_Arlington</td>
</tr>
<tr>
<td>30</td>
<td>34.064688346</td>
<td>-117.303911477</td>
<td>Santa_Ana_River_AT_E_Street_NR_San_Bernardino</td>
</tr>
<tr>
<td>31</td>
<td>33.889166670</td>
<td>-117.561944440</td>
<td>Temescal_Creek_AB_Main_Street_AT_Corona</td>
</tr>
<tr>
<td>32</td>
<td>33.982777780</td>
<td>-117.598611110</td>
<td>Cucamonga_Creek_NR_Mira_Loma</td>
</tr>
<tr>
<td>33</td>
<td>34.003888890</td>
<td>-117.726111110</td>
<td>Chino_Creek_AT_Schaefer_Avenue_NR_Chino</td>
</tr>
<tr>
<td>34</td>
<td>34.114206940</td>
<td>-117.096661940</td>
<td>Seven_Oaks_Dam_Outlet</td>
</tr>
<tr>
<td>35</td>
<td>34.252500000</td>
<td>-117.525777800</td>
<td>Middle_Fork_Lytle_Creek_Gage</td>
</tr>
<tr>
<td>36</td>
<td>34.263888890</td>
<td>-117.401388890</td>
<td>Ridge_Top_Gage_NR_Devore</td>
</tr>
</tbody>
</table>
Step 3: Sub-basin delineation
Seven Oaks Dam Outlet
Step 3: Sub-basin delineation

Prado Dam Gage
Step 3: Sub-basin delineation
Adams Street Gage
Step 4: Developing the VIC routing models

Consists of two parts

1. Developing flow direction files - represent the flow network

2. Developing flow fraction files – fraction of grid cell covered by the sub-basin

Use Santa Ana River Adams Street Gage as the example
Step 4: Developing the VIC routing models
Adams Street Gage

- Developing flow direction files - represent the flow network

- Model grid, 1/8th degree x 1/8th degree (lat x lon) ~7 mi x 7 mi or ~12 km x 12 km
Step 4: Developing the VIC routing models
Adams Street Gage

- Developing flow direction files - represent the flow network

- Model grid, 1/8\textsuperscript{th} degree x 1/8\textsuperscript{th} degree (lat x lon) ~7 mi x 7 mi or ~12 km x 12 km

- One of eight (8) flow direction assigned to each grid, USGS HydroSHEDS data, http://hydrosheds.cr.usgs.gov/
Step 4: Developing the VIC routing models

Adams Street Gage

Basin outlet represented by -9

Similar flow direction files were developed for all the 36 sites in the Santa Ana River Basin
Step 4: Developing the VIC routing models

Consists of two parts

1. Developing flow direction files - represent the flow network

2. Developing flow fraction files – fraction of grid cell covered by the sub-basin

Use Santa Ana River Adams Street Gage as the example
Step 4: Developing the VIC routing models

Adams Street Gage

Fraction of grid cell covered by the sub-basin, total = 40.2063

Similar flow fraction files were developed for all the 36 sites in the Santa Ana Basin.
Step 5: Flow routing using the WWCRA gridded runoff

VIC Routing Model

BCSD Climate and Hydrology Projections Website
http://gdo-dcp.ucrlnl.org/downscaled_cmip3_projections/dcpInterface.html
WHAT ANALYSIS WAS DONE USING THE HYDROLOGY PROJECTIONS?

1. Background. Acronyms, definitions, assumptions, and hydrology model overview.

2. How were the hydrologic projections developed for the Santa Ana Watershed? Detailed description of the hydrologic projections development process, specifically streamflow.

3. What analysis was done using the hydrology projections? Detailed description of analysis of change and statistics used.

4. Results. All results are preliminary and draft.

5. Example analysis. Change in runoff using the hydrologic projections website hosted at Lawrence Livermore National Lab (LLNL).

6. Summary

7. Next Steps
Assumptions

• 10-year base or reference hydrology period, water years 1990-1999. 1990s.

• Three (3) future look ahead periods:
  – water years 2020-2029. 2020s.
  – water years 2050-2059. 2050s.
  – water years 2070-2079. 2070s.

• All analysis are made using modeled data from 112 BCSD CMIP-3 projections and VIC simulations.
Hydrology Projections Analysis

- Change analysis between the base period (1990s) and future period (2020s, 2050s, 2070s), how were the changes calculated?

- Precipitation – percentage (%) change. Steps - for example to estimate change in the 2020s from the 1990s. For a given grid cell in the Basin, and given projection [iproj] (recall, total number of projections is 112)

  1. Calculate decade mean total precipitation (P) for the two decades 1990s (water years 1990-1999, iper=1) and 2020s (water years 2020-2029, iper=2).

  2. Next, calculate percentage change (pchange) of projection iproj,

     \[ pchange[iproj] = 100 \times \left( \frac{P[iproj, 2] - P[iproj, 1]}{P[iproj, 1]} \right) \]

  3. Finally, calculate the median change from all the 112 projections - ensemble median change.

  4. Repeat Steps 1 through 3 for all the grid cells in the Basin.
Hydrology Projections Analysis

• Change analysis between the base period (1990s) and future period (2020s, 2050s, 2070s), how were the changes calculated?

• Snow Water Equivalent (SWE) – calculations similar to precipitation.

• Temperature (T) – steps similar to precipitation but not percentage change,
  1. Calculate decade mean temperature (T) for the two decades 1990s (water years 1990-1999, iper=1) and 2020s (water years 2020-2029, iper=2).
  2. Next, calculate change in decade mean temperature value for projection iproj,
     \[ \text{change} = (T[iproj, 2] - T[iproj, 1]) \]
  3. Finally, calculate the median change from all the 112 projections - ensemble median change.
  4. Repeat Steps 1 through 3 for all the grid cells in the Basin.

• More details/examples during presentation of results in subsequent slides. …
1. **Background.** Acronyms, definitions, assumptions, and hydrology model overview.

2. **How were the hydrologic projections developed for the Santa Ana Watershed?** Detailed description of the hydrologic projections development process, specifically streamflow.

3. **What analysis was done using the hydrology projections?** Detailed description of analysis of change and statistics used.

4. **Results.** *All results are preliminary and draft.*

5. **Example analysis.** Change in runoff using the hydrologic projections website hosted at Lawrence Livermore National Lab (LLNL).

6. **Summary**

7. **Next Steps**

RESULTS
Hydrology Projections
Results

- Change analysis between the base/reference period (1990s) and three future periods (2020s, 2050s, 2070s)
  1. Precipitation
  2. Temperature
  3. April 1st SWE
  4. Flow

- Spatial distribution and temporal trends

- Santa Ana R. Adams St. Gage
Hydrology Projections
Spatial Distribution of Precipitation (P)

- The ensemble-median change shows some increase in prcp over the basin during the 2020s’ decade from the 1990s’ reference.

- By the 2050s there is decline in prcp from the 1990s reference decade.

- Increased decline in prcp continues through to the 2070s decade from the 1990s reference decade.
Hydrology Projections
Spatial Distribution of Temperature (T)

- The ensemble median change for the 2020s’, 2050s’, and 2070s’ decades relative to the 1990s shows an increasing temperature value throughout the Basin.
Hydrology Projections
Snow Water Equivalent (SWE)

- Spatial distribution of April 1st SWE – persistent decline through the future decades (2020s, 2050s, 2070s) from the 1990s’ distribution.
Hydrology Projections P, T, SWE, Flow

- Temporal trends – solid line is the median, 5\textsuperscript{th} and 95\textsuperscript{th} percentile bounds.
- P – longer-term decreasing trend
- T – increasing trend
- SWE – decreasing trend
- Flow – longer-term decreasing trend
Hydrology Projections
Flow Impacts

- Annual and seasonal streamflow impacts

- 2020s – increase in annual runoff and winter (Dec-Mar) runoff, decrease in spring-summer (Apr-Jul) runoff from the 1990s reference

- 2050s – decrease in annual, winter, spring-summer runoff from the 1990s reference

- 2070s - decrease in annual, winter, spring-summer runoff from the 1990s reference
### Summary of Impacts
Santa Ana River Adams St. Gage

<table>
<thead>
<tr>
<th>Hydroclimate Metric (change from 1990s)</th>
<th>2020s</th>
<th>2050s</th>
<th>2070s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation (%)</td>
<td>0.67</td>
<td>-5.41</td>
<td>-8.09</td>
</tr>
<tr>
<td>Mean Temperature (deg F)</td>
<td>1.22</td>
<td>3.11</td>
<td>4.10</td>
</tr>
<tr>
<td>April 1st SWE (%)</td>
<td>-38.93</td>
<td>-80.40</td>
<td>-93.07</td>
</tr>
<tr>
<td>Annual Runoff (%)</td>
<td>2.60</td>
<td>-10.08</td>
<td>-14.61</td>
</tr>
<tr>
<td>Dec-Mar Runoff (%)</td>
<td>9.82</td>
<td>-3.01</td>
<td>-6.38</td>
</tr>
<tr>
<td>Apr-Jul runoff (%)</td>
<td>-6.35</td>
<td>-25.24</td>
<td>-31.39</td>
</tr>
</tbody>
</table>

Similar analysis was done for all the 36 sites in the Santa Ana Basin.
1. **Background.** Acronyms, definitions, assumptions, and hydrology model overview.

2. **How were the hydrologic projections developed for the Santa Ana Watershed?** Detailed description of the hydrologic projections development process, specifically streamflow.

3. **What analysis was done using the hydrology projections?** Detailed description of analysis of change and statistics used.

4. **Results.** All results are preliminary and draft.

5. **Example analysis.** Change in runoff using the hydrologic projections website hosted at Lawrence Livermore National Lab (LLNL).

6. **Summary**

7. **Next Steps**

**EXAMPLE ANALYSIS**
Example: Runoff Impact
Santa Ana R. Adams St. Gage

http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html
1. Background. Acronyms, definitions, assumptions, and hydrology model overview.

2. How were the hydrologic projections developed for the Santa Ana Watershed? Detailed description of the hydrologic projections development process, specifically streamflow.

3. What analysis was done using the hydrology projections? Detailed description of analysis of change and statistics used.

4. Results. All results are preliminary and draft.

5. Example analysis. Change in runoff using the hydrologic projections website hosted at Lawrence Livermore National Lab (LLNL).

6. Summary

7. Next Steps

SUMMARY
Summary

- Developed hydrologic projections from climate change projections for the Santa Ana Watershed. 36 sites across the Santa Ana Basin.

- Analyzed the hydrologic projections to support updating of the IRWMP plan, i.e. OWOW 2.0.

- Example analysis on how runoff impacts can be calculated from the WWCRA gridded hydrology.
1. Background. Acronyms, definitions, assumptions, and hydrology model overview.

2. How were the hydrologic projections developed for the Santa Ana Watershed? Detailed description of the hydrologic projections development process, specifically streamflow.

3. What analysis was done using the hydrology projections? Detailed description of analysis of change and statistics used.

4. Results. All results are preliminary and draft.

5. Example analysis. Change in runoff using the hydrologic projections website hosted at Lawrence Livermore National Lab (LLNL).

6. Summary

7. Next Steps

NEXT STEPS
Next Steps

• Documenting all the analysis.

• Performing “as-needed” additional analysis.

• Developing decision support tools.