Managing Water Supplies during Extreme Weather

DENVER WATER
Managing Water Supplies during Extreme Weather

- Denver Water System
- Drought of 2002
- Blizzard of 2003
- Lessons Learned
- Opportunities

Marc Waage, Manager of Raw Water Supply
John Loughry, Chief Planner
Denver Water
Denver Board of Water Commissioners
Water Collection System

COLLECTION SYSTEMS

- SOUTH PLATTE
- MOFFAT TUNNEL
- ROBERTS TUNNEL
- WILLIAMS FORK WATERSHED

TREATMENT PLANT

CONTINENTAL DIVIDE

STREAM OR RIVER

TUNNEL, CANAL OR DITCH
Extreme Spring Weather

2002 Drought
- Single driest year on record (~300 yr event)
- First time reservoirs lost storage during “runoff”
- Record low storage, worst restrictions
- State’s biggest fire burns primary watershed

2003 Blizzard
- Second largest storm in Denver history
- Wettest March on record
- Record recovery in storage levels
  (42% full to 86% full)
Dry Year Snow Pack, Precip, and Runoff
Denver Water Collection System

- Precip & SWE, in
- Runoff, AF

Period: 1954-2002
Apr 1 SWE
Apr-June Precip
Apr-Jul Runoff

- Average 1954
- 1963
- 1977
- 1981
- 2002

- Precip & SWE, in
- Runoff, AF

- Apr 1 SWE
- Apr-June Precip
- Apr-Jul Runoff
Dry Year Snow Pack, Precip, and Runoff
Denver Water Collection System

- Average: 66%
- 1954: 65%
- 1963: 46%
- 1977: 45%
- 1981: 63%
- 2002: 46%

Period: 1954-2002
April 1 SWE
April-June Precip
April-July Runoff

- Apr 1 SWE: 12 in
- Apr-June Precip: 6 in
- Apr-Jul Runoff: 4 in

Assessment:
- April 1, 2002 % Full = 77% (Normal = 82%)
Dry Year Snow Pack, Precip, and Runoff
Denver Water Collection System


- Apr 1 SWE
- Apr-June Precip
- Apr-Jul Runoff

<table>
<thead>
<tr>
<th>Year</th>
<th>Precip &amp; SWE, in</th>
<th>Runoff, AF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>12</td>
<td>450,000</td>
</tr>
<tr>
<td>1954</td>
<td>8</td>
<td>400,000</td>
</tr>
<tr>
<td>1963</td>
<td>7</td>
<td>350,000</td>
</tr>
<tr>
<td>1977</td>
<td>6</td>
<td>300,000</td>
</tr>
<tr>
<td>1981</td>
<td>5</td>
<td>250,000</td>
</tr>
<tr>
<td>2002</td>
<td>4</td>
<td>200,000</td>
</tr>
</tbody>
</table>

Period: 1954-2002
Apr 1 %Full = 77% (Normal = 82%)
Variation of Annual Natural Flow
South Platte River at South Platte

Average = 296,000 af

2002 = 63,000 af (21% of average)

Example of Mother Nature’s irregularity.
Projections of July 1 Total Storage in Denver's System

Date of Projection

4/1/02 5/1/02 6/1/02

Percent Full

87% 75% 66%

Drought Response
Stage 1-Voluntary
Stage 2-Mandatory
Stage 3-No Irrigation
Dillon Reservoir/Frisco Marina-June 2002

“Drought Barometer”
Hayman Fire – 130,000 acres in South Platte Watershed
March 2003 Blizzard
March 17-20, 2003 Snowfall Totals
What a long, strange trip it’s been
Hang On For Spring Weather!
Cumulative Precipitation Above Denver Water Facilities in the South Platte Basin

Inches of Precipitation

- **Average (1979-2003)**
- **2004-2003**
- **2003-2002**
- **2002-2001**
March proves cruelest month for metro-area water planners

By Theo Stein
Denver Post Environment Writer

In Colorado, March can come in like a lamb and go out like a lion - a trait that has Denver Water in limbo-land as planners try to predict how much water will be available for its 1 million customers this summer.

"March has been the turning point each of the last two years," Marc Waage, the agency's raw water manager, told board members at their monthly meeting Wednesday.
Water Supply Lessons from Extreme Weather Events

• Prepare for intensity
  – Complete Drought Plan, Be nimble

• Know the odds
  – ‘worst on record’
  – Probabilistic forecasts

• Know your risk aversion
The graph illustrates the comparison between triggers and actual restrictions over a period from April 2002 to January 2004.

**Triggers vs. Actual Restrictions**

The graph shows the percent full values for both Stage 1 and Stage 2. The x-axis represents the months from April 2002 to January 2004, while the y-axis represents the percent full values ranging from 0% to 100%.

- Stage 1 was triggered on June 5, 2002, and actual restrictions began on July 1, 2002.
- Stage 2 was triggered on Oct 15, 2003.

At the peak, the actual restrictions reached 84% in July 2003, and by January 2004, they decreased to 73%.
Water Supply Lessons from Extreme Weather Events

- Know your neighbors
- “Can’t conserve your way out of a drought” - Chips Barry, 2002
- Fires like drought
- More money
- Snow is has better manners
- Perception is everything
Water Supply Opportunities from Extreme Weather Events

Customer Awareness

- More Conservation
- More Supply

Be better prepared
More Information

• DenverWater.org

• Marc.Waage@DenverWater.org

• 303-628-6000
BACKUP INFORMATION
Don’t have a fire at the same time you have a drought

- Droughts are hard enough to deal with by themselves!
- Hayman fire dramatically complicated DW’s operational problems in the 2002 drought
  - Actually had another major fire in 2002 (Schoonover)
- Improvements in forest management could reduce the risk of fire and damage to watersheds
Fire Burn Severity Hayman Fire
NRCS April 1, 2002 Forecasts
Spring Runoff, KAF

<table>
<thead>
<tr>
<th>Basin</th>
<th>Chance of Exceeding</th>
<th>Actual Runoff</th>
<th>% of Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10%</td>
<td>50%</td>
<td>90%</td>
</tr>
<tr>
<td>South Platte (Apr-Sep)</td>
<td>162</td>
<td>93</td>
<td>65</td>
</tr>
<tr>
<td>Upper CO (WF+DL, Apr-Jul)</td>
<td>232</td>
<td>164</td>
<td>99</td>
</tr>
</tbody>
</table>

**Conclusion:**

Less than 10% chance on April 1 that actual runoff would occur
Current % of Average: 63%
Last Week % of Average: 62%

Data are from the 7 Snotel stations above Denver Water's Upper South Platte diversion facilities.
Current % of Average: 80%
Last Week % of Average: 81%

Data are from the 8 Snotel stations above Denver Water's Upper Colorado diversion facilities.
Effect of Future Weather

- **DRY WEATHER FORECAST**: 10% Chance of Drier
- **NORMAL WEATHER FORECAST**: 40% Chance of In Between
- **WET WEATHER FORECAST**: 40% Chance of Wetter
- **2002 Weather**:

  Other Variables:
  - Water Rights
  - System Performance
Effect of Future Weather

2002 Weather

Other Variables:
* Water Rights
* System Performance
## Forecasted July 1 Reservoir Storage (% Full)
(Based on March 1 conditions)

<table>
<thead>
<tr>
<th>Drought Response</th>
<th>Dry</th>
<th>Normal</th>
<th>Wet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage 1 (Voluntary)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross</td>
<td>79%</td>
<td>92%</td>
<td>94%</td>
</tr>
<tr>
<td>Net</td>
<td>76%</td>
<td>91%</td>
<td>94%</td>
</tr>
<tr>
<td><strong>Stage 2 (Mandatory)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross</td>
<td>81%</td>
<td>93%</td>
<td>94%</td>
</tr>
<tr>
<td>Net</td>
<td>78%</td>
<td>92%</td>
<td>94%</td>
</tr>
</tbody>
</table>

### Notes:

1. There is about a 10% chance that actual precipitation will be less than that assumed for the "dry" scenario and about a 10% chance that actual precipitation will be greater than that assumed for the "wet" scenario.

2. "Net" storage excludes the water in Dillon Reservoir that is owed to Green Mountain Reservoir.

3. Drought Response: Both Stage 1 and Stage 2 assume March water use at winter level. April through June use for Stage 1 is 9400 AF below normal; for Stage 2 it is 20,800 AF below normal.
Watershed

Snow Fall → Snow Melt

Snow Melt → Rain → Evaporation

Evaporation → Soil & Ground Water

Runoff Forecast → Upstream Diversion

Canals → Tunnels

Evaporation → Bypass Requirements Senior Water Rights

Use → City

Storage Forecast
SUPPLY FORECASTS

Runoff forecasts for each basin
(From NRCS)

Operation Model

Variables
1. River calls
2. Diversions
3. Demand
4. Exchanges
5. Runoff timing
(all weather dependent)

Predicted Reservoir Levels

Dry weather
(10% Probability)

Dry weather
(10% Probability)

Normal weather
(50% Probability)

Normal weather
(50% Probability)

Wet weather
(10% Probability)

Wet weather
(10% Probability)
Water Stored April 1 - July 31

Water Stored, acre-feet

Dillon Reservoir Inflows

Flow (cfs)

April 1
May 1
June 1
July 1
Aug 1

Dated June 1, 2002 through Aug 1, 2004:

- Blue line: 2004
- Black line: 1988
- Green line: 2003
- Red line: 2002

1988 runoff was close to average.
1991 runoff was close to average.
1993 runoff was close to average.
1999 runoff was close to average.
## Storage Forecast

<table>
<thead>
<tr>
<th>Forecast Date</th>
<th>Dry Weather</th>
<th>Normal Weather</th>
<th>Wet Weather</th>
<th>Dry Weather</th>
<th>Normal Weather</th>
<th>Wet Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>February</td>
<td></td>
<td>96%</td>
<td></td>
<td>42%</td>
<td>58%</td>
<td>76%</td>
</tr>
<tr>
<td>March</td>
<td></td>
<td>94%</td>
<td></td>
<td>51%</td>
<td>65%</td>
<td>80%</td>
</tr>
<tr>
<td>April</td>
<td></td>
<td>87%</td>
<td></td>
<td>66%</td>
<td>79%</td>
<td>87%</td>
</tr>
<tr>
<td>May</td>
<td>66%</td>
<td>70%</td>
<td></td>
<td>78%</td>
<td>82%</td>
<td>88%</td>
</tr>
<tr>
<td>Actual July 1 Storage:</td>
<td>66%</td>
<td></td>
<td></td>
<td></td>
<td>84%</td>
<td></td>
</tr>
</tbody>
</table>
U.S. Drought Monitor

February 10, 2004
Valid 7 a.m. EST

Drought Intensity:
- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:
- ✔ Delineates dominant impacts
- A = Agricultural (crops, pastures, grasslands)
- H = Hydrological (water)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm

Released Thursday, February 12, 2004
Author: Michael Hayes, NDMC
Cumulative Precip Graphs
Cumulative Precipitation Above Denver Water Facilities in the South Platte Basin

Inches of Precipitation

Average (1979-2003)
2003-2004
2002-2003
2001-2002
2000-2001
1999-2000
Cumulative Precipitation Above Denver Water Facilities in the Colorado Basin

Inches of Precipitation

- Orange line: 2003-2004
- Blue line: 2002-2003
- Green line: 2001-2002
- Red line: 2000-2001
- Purple line: 1999-2000

Dates:
- 10/1/04
- 10/15/04
- 10/29/04
- 11/12/04
- 11/26/04
- 12/10/04
- 12/24/04
- 1/7/05
- 1/21/05
- 2/4/05
- 2/18/05
- 3/4/05
- 3/18/05
- 4/1/05
- 4/15/05
- 4/29/05
- 5/13/05
- 5/27/05
- 6/10/05
- 6/24/05
- 7/8/05
- 7/22/05
- 8/5/05
- 8/19/05
- 9/2/05
- 9/16/05
- 9/30/05
Cumulative Precipitation Above Denver Water Facilities in the South Platte Basin

Inches of Precipitation

- **Average (1979-2003)**
- **2004-2003**
- **2003-2002**
- **2002-2001**
Cumulative Precipitation Above Denver Water Facilities in the Colorado Basin

Inches of Precipitation

- Average (1979-2003)
- 2004-2003
- 2003-2002
- 2002-2001
HISTORIC SNOTEL GRAPHS
Denver's South Platte Watershed
Snow Water Equivalent (1980-1984)

Data are from the 7 Snotel stations above Denver Water's
Upper South Platte diversion facilities.
Denver's South Platte Watershed
Snow Water Equivalent (1985-1989)

Data are from the 7 Snotel stations above Denver Water's Upper South Platte diversion facilities.
Denver's South Platte Watershed
Snow Water Equivalent (1990-1994)

Data are from the 7 Snotel stations above Denver Water's
Upper South Platte diversion facilities.
Denver’s South Platte Watershed

Data are from the 7 Snotel stations above Denver Water’s Upper South Platte diversion facilities.
Denver's South Platte Watershed

Average SWE (inches)

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Denver's Colorado Watershed
Snow Water Equivalent (1980-1984)

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Denver's Colorado Watershed
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Data are from the 8 Snotel stations above Denver Water's Upper Colorado diversion facilities.
Denver's Colorado Watershed

Data are from the 8 Snotel stations above Denver Water's Upper Colorado diversion facilities.
Precipitation from April - June for the South Platte Basin

Average (10.1)
Precipitation from April - June for the Colorado Basin

Average (8.4)