Idaho Collaborative Cloud Seeding Program

Overview

- History of Cloud Seeding in Idaho
- Current Projects
- Program Budget
- Priorities & Next Steps
- FAQs

Photo Courtesy of Joel Zimmer, WMI

History of Cloud Seeding in Idaho

Water Year	Northern Idaho	Southwestern Idaho	Southern Idaho	Southeastern Idaho
1950	-	-	-	-
1951	*	-	-	-
1952	-	-	-	-
1953	*	-	-	-
1954	*	-	*	*
1955	*	*	*	*
1956	*	*	-	*
1957	*	-	-	*
1958	*	-	-	*
1959	*	-	-	*
1960	*	*	-	*
1961	-	*	-	*
1962	-	*	-	*
1963	-	-	-	*
1964	-	-	-	*
1965	-	-	-	*
1966	-	-	-	*
1967	*	-	-	*
1968	*	-	-	*
1969	*	-	-	*
1970	*	-	-	*
1971	*	-	-	-
1972	-	-	-	-
1973	-	-	-	-
1974	*	-	-	-
1975	-	-	-	-
1976	-	-	-	-
1977	-	-	-	-
1978	-	-	-	-
1979	-	-	-	-
1980	-	-	-	*
1981	-	-	-	*
1982	-	-	-	*
1983	-	-	-	-
1984	-	-	-	-
1985	-	-	-	-

Water Year	Payette	Boise	Wood	Northern Upper Snake	Southern/Eastern Upper Snake
1986	-	-	-	-	-
1987	-	-	-	-	-
1988	-	-	-	-	-
1989	-	-	-	*	*
1990	-	-	-	-	*
1991	-	-	-	-	-
1992	-	-	-	-	*
1993	-	*	-	*	*
1994	-	*	-	-	-
1995	-	*	-	-	*
1996	-	*	-	-	-
1997	*	-	-	* | LIS, $	-
1998	-	-	-	* | LIS, $	-
1999	-	-	-	* | LIS, $	-
2000	-	-	-	* | LIS, $	-
2001	-	-	-	* | LIS, $	-
2002	-	*	-	* | LIS, $	* | LIS, $
2003	* | IPC	*	-	-	* | LIS, $
2004	* | IPC	*	-	* | LIS, $	* | LIS, $
2005	* | IPC	*	-	-	* | LIS, $
2006	* | IPC	-	-	* | LIS, $	-
2007	* | IPC	-	-	* | LIS, $	-
2008	* | IPC	*	-	* | LIS, IPC, $	* | LIS, IPC, $
2009	* | IPC	*	-	* | LIS, IPC, $	* | LIS, IPC, $
2010	* | IPC	-	-	* | LIS, IPC, $	* | LIS, IPC, $
2011	* | IPC	*	-	* | LIS, IPC, $	* | LIS, IPC, $
2012	* | IPC	*	-	* | LIS, IPC, $	* | LIS, IPC, $
2013	* | IPC	-	* | IPC, $	* | LIS, IPC, $	* | LIS, IPC, $
2014	* | IPC	*	* | IPC, $	* | LIS, IPC, $	* | LIS, IPC, $
2015	* | IPC	* | IPC, $	* | IPC, $	* | LIS, IPC, $	* | LIS, IPC, $
2016	* | IPC	* | IPC, $	* | IPC, $	* | LIS, IPC, $	* | LIS, IPC, $
2017	* | IPC	* | IPC, $$	* \| IPC, $$	* | LIS, IPC, $$	* \| LIS, IPC, $$
2018	* | IPC	* | IPC, $$	* \| IPC, $$	* | LIS, IPC, $$	* \| LIS, IPC, $$
2019	* | IPC	* | IPC, $$	* \| IPC, $$	* | LIS, IPC, $$	* \| LIS, IPC, $$
2020	* | IPC	* | IPC, $$	* \| IPC, $$	* | LIS, IPC, $$	* \| LIS, IPC, $$
2021	* | IPC	* | IPC, $$	* \| IPC, $$	* | LIS, IPC, $$	* \| LIS, IPC, $$
2022	* | IPC	* | IPC, $$	* \| IPC, $$	* | LIS, IPC, $$	* \| LIS, IPC, $$
2023	* | IPC	* | IPC, $$	* \| IPC, $$	* | LIS, IPC, $$	* \| LIS, IPC, $$

* Cloud Seeding Ops; Idaho Power Company (IPC); Let it Snow (LIS) ; $ Stakeholder Funding ; $ State Funding

What is Idaho's Collaborative Cloud Seeding Program?

- Unique partnership between:
  - Idaho Water Resource Board (IWRB)– State of Idaho
  - Idaho Power Company (IPC)
  - Stakeholders/Local water users in basins of operation
- IPC operates the program, the State and local water users participate in program funding
- Currently includes the Boise, Wood, Upper Snake River Basins of Idaho
- IPC operates independent project in the Payette River Basin, in coordination with the collaborative program.

History of the Collaborative Program

- 1990's, Idaho Power Company (IPC) began investigating cloud seeding to support hydropower
- 2003, first operational program in the Payette River Basin– IPC
- 2008, ESPA CAMP → implementation of 5-year pilot project in the Upper Snake Basin– IPC
- Water users in the Wood and Boise River Basins partnered with IPC to begin new projects
- 2014, the IWRB began participation in program funding with capital for new infrastructure
- 2016, the IWRB began contributing towards program operations and modeling
- 2019, program reached existing build-out (3 aircraft, 57 remote generators, network of weather instrumentation)

Idaho Collaborative Cloud Seeding Program

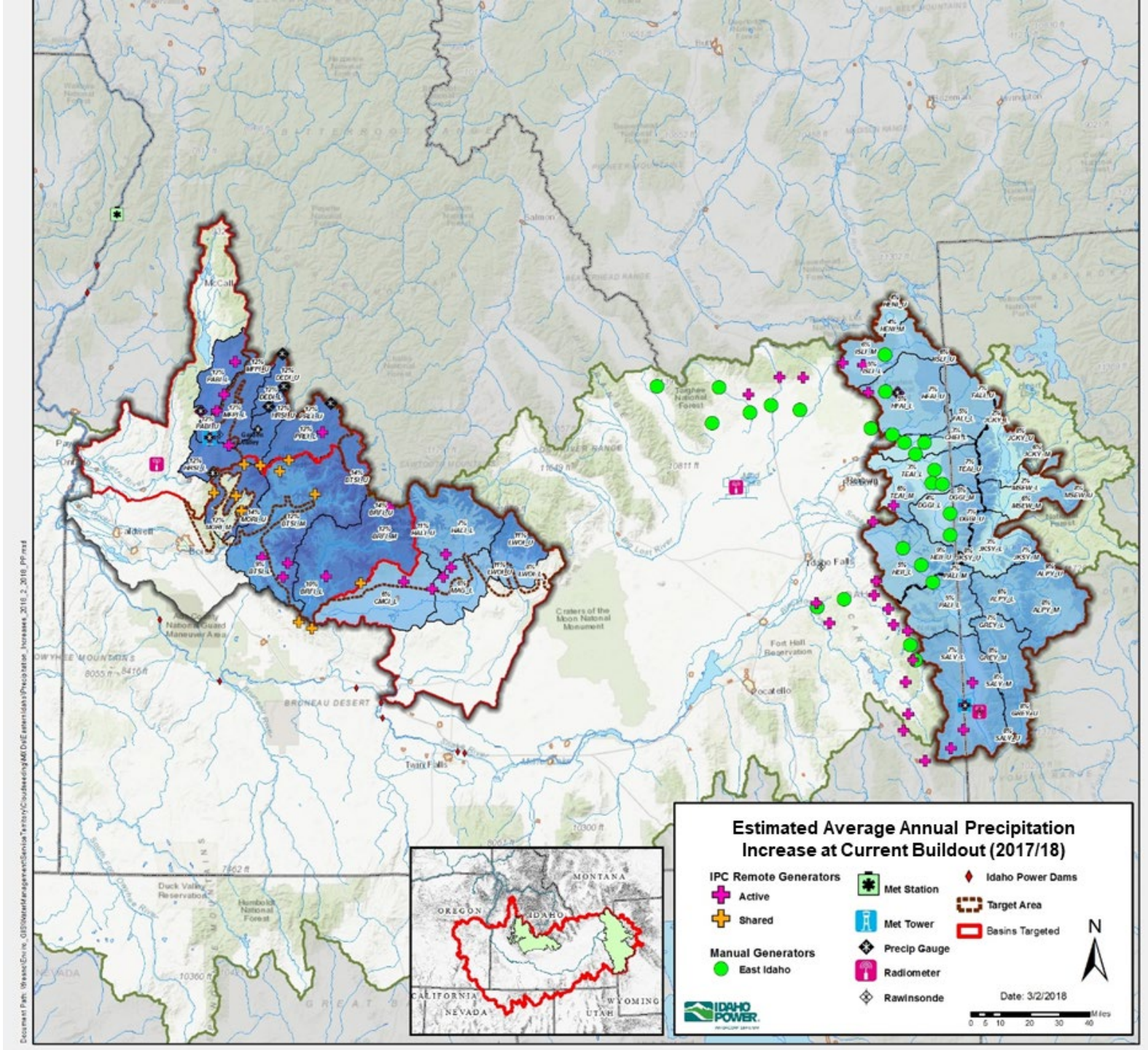
- 57 Remote Ground Generators

- 3 Aircraft

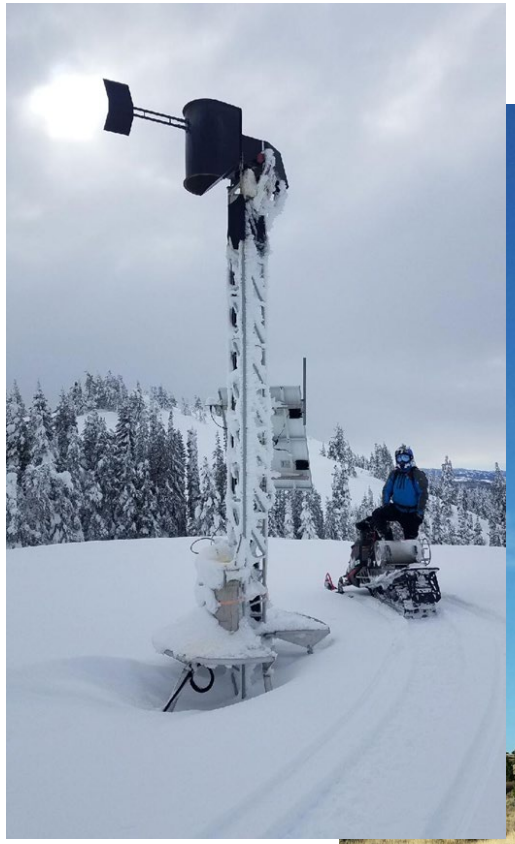
- Network of Weather Instrumentation

- Sophisticated Modeling technologies

- Atmospheric Science Team



Cloud Seeding Infrastructure



Remote Ground Generators

Aircraft

Burn-in-Place (BIP) flares are released in cloud

Ejectable (EJ) flares are released above cloud

Images Courtesy of Idaho Power Company and Ice Crystal Engineering

Cloud Seeding Infrastructure

Weather Instrumentation

Wind Direction?

Wind Speed?

SLW Content?

Temperatures?

Atmospheric?

Pressure?

SWE?

More…

Images Courtesy of Idaho Power Company

Program Operations

- Guidelines for the operation of cloud seeding– American Society of Civil Engineers (ASCE)
- Annual Operational Planning “Ground School”
    - When, Where, How, Communications
- Suspension Criteria to mitigate risks for flooding/avalanche or other hazards
- Forecasting & Analysis
    - Weather Instrumentation (precipitation gages, balloons, radiometers, etc.)
    - High Resolution modeling, WRF Models
- Supported by team of atmospheric scientists, 24-7

West Central Mountains Projects

Estimated Average Additional Runoff (unregulated) &

Current Project Costs (Annually)

Boise River Basin– 273 KAF | $910K

Wood River Basin – 112 KAF | $670K

Payette River Basin* – 223 KAF | $870K

WCM Total: 608KAF |$2.45M

**Independent project operated by Idaho Power Company in coordination with the Collaborative. 100% Funded by IPC.*

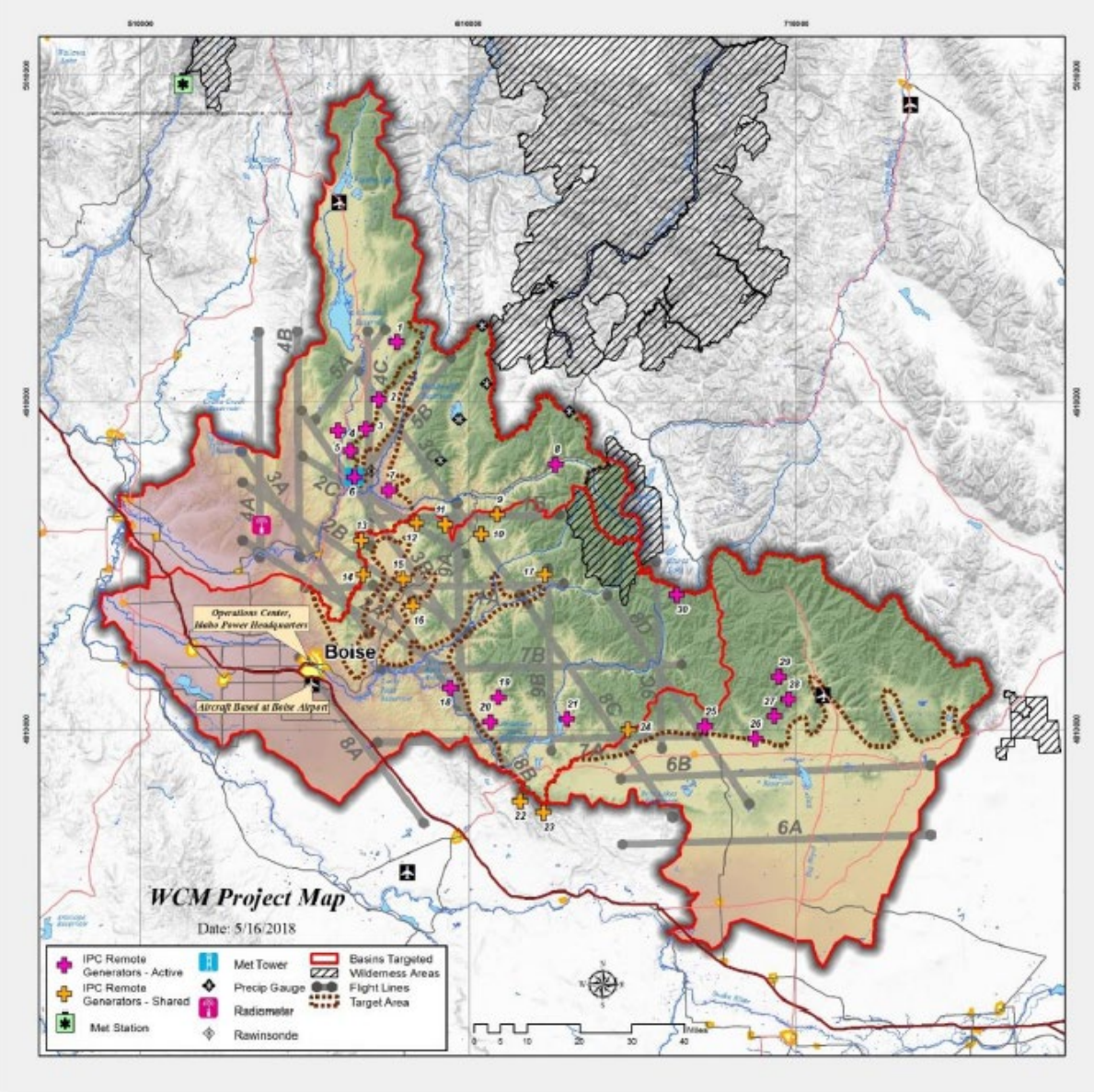
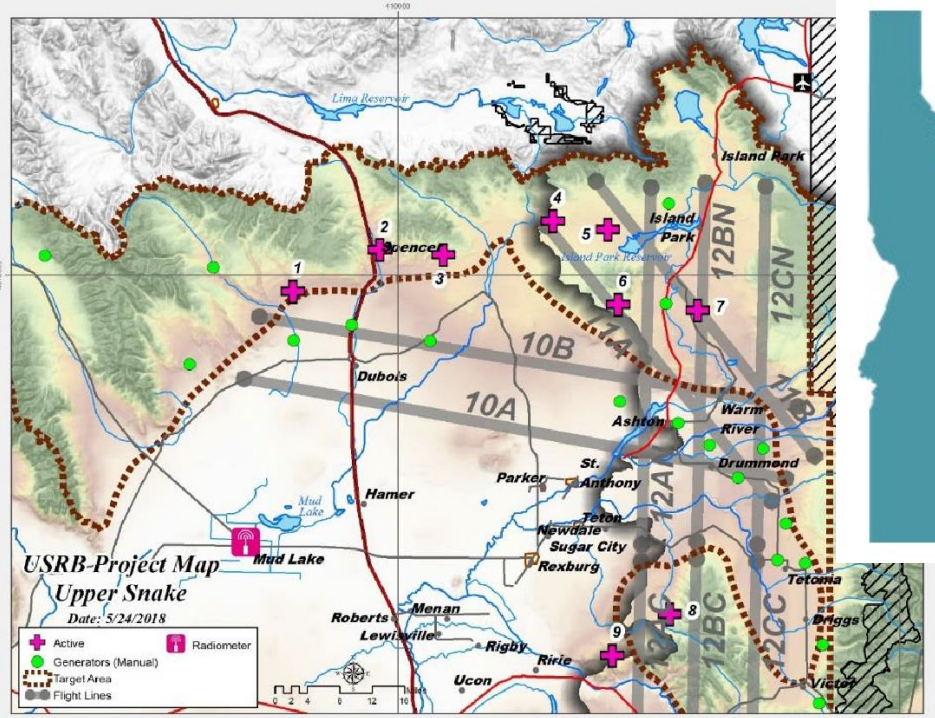


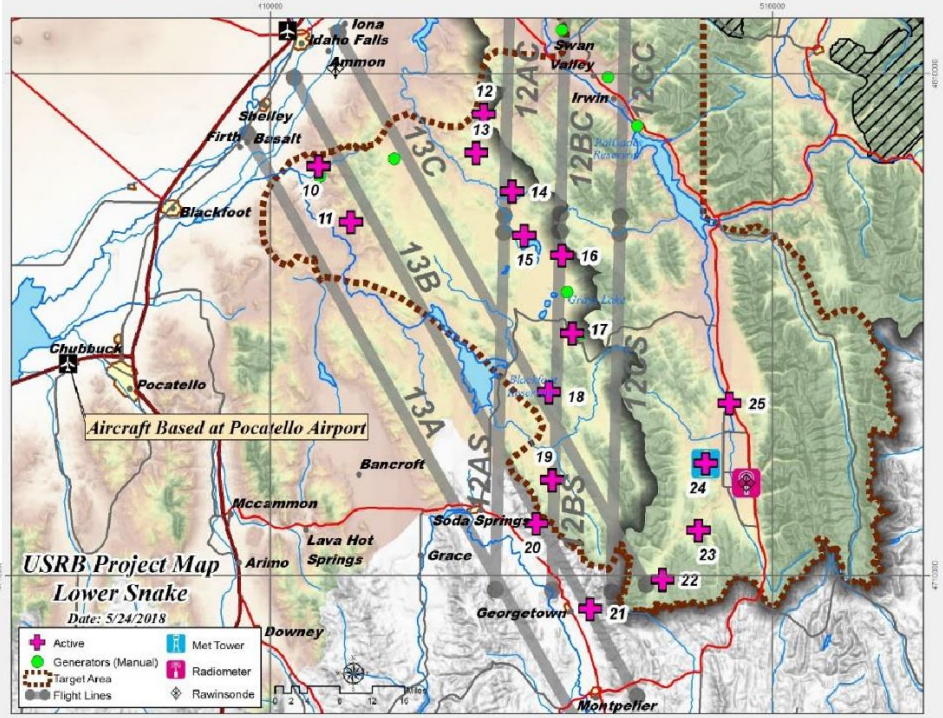
Figure 5: Central Mountains Cloud Seeding Project

Upper Snake River Basin Projects

Northern Upper Snake | 168 KAF Avg Annual



Southern Upper Snake | 464 KAF Avg Annual



Upper Snake River Basin | 632 KAF | $1.54M

Collaborative Program Summary

Current Annual Operations Cost: $4,200,000

Average Annual Runoff Generated: 1,240,000 AF

Estimated Cost Per Acre Foot: $3.4/AF

Current Priorities

- **Develop Program Structure–** *What is the State's roll? The roll of stakeholders?*
- **Secure long term collaborative agreements–** *How will the program be funded long term?*
- **Assess opportunities for program expansion or enhancement–** *Can we grow the program/be more effective?*
- **Ongoing monitoring and analysis–** *How will we ensure the programs continued effectiveness?*

Legislation

Idaho House Bill 266 (*HB266, 2021*)

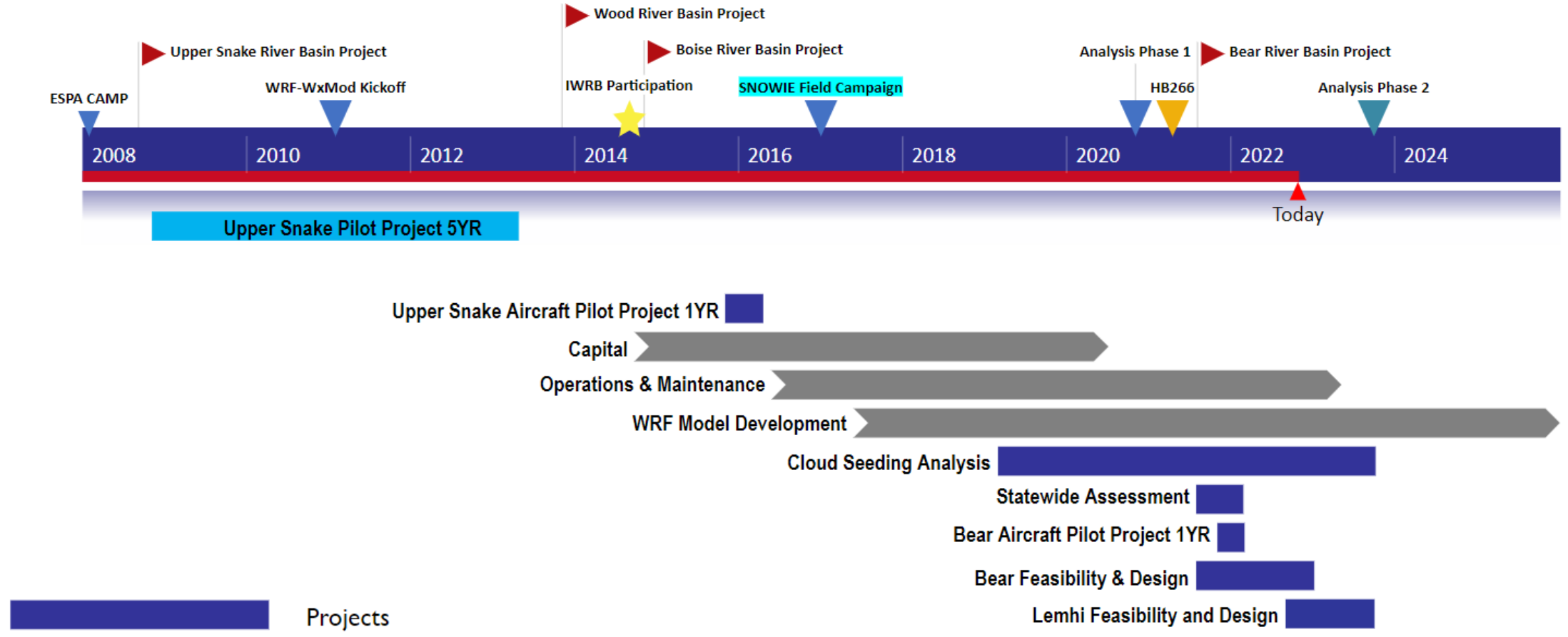
Directed the IWRB to:

1. Continue analysis of existing cloud seeding projects
2. Complete an assessment of opportunities for cloud seeding in other basins
3. Authorize cloud seeding programs in Idaho

Provides the IWRB authority to:

- Sponsor or develop local or statewide cloud seeding programs
  - *State funds may only be used in basins where the IWRB finds that existing water supplies are insufficient to support existing water rights, water quality, recreation, or fish and wildlife*

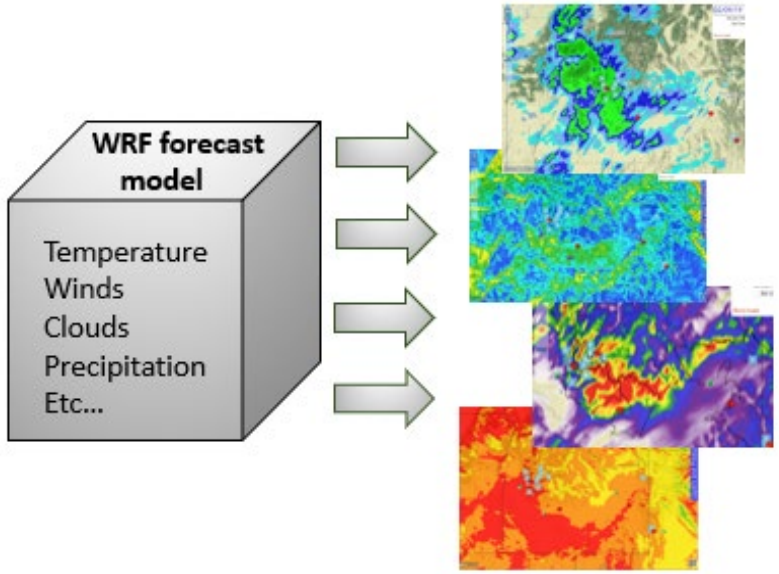
Idaho Cloud Seeding Program Development



Modeling

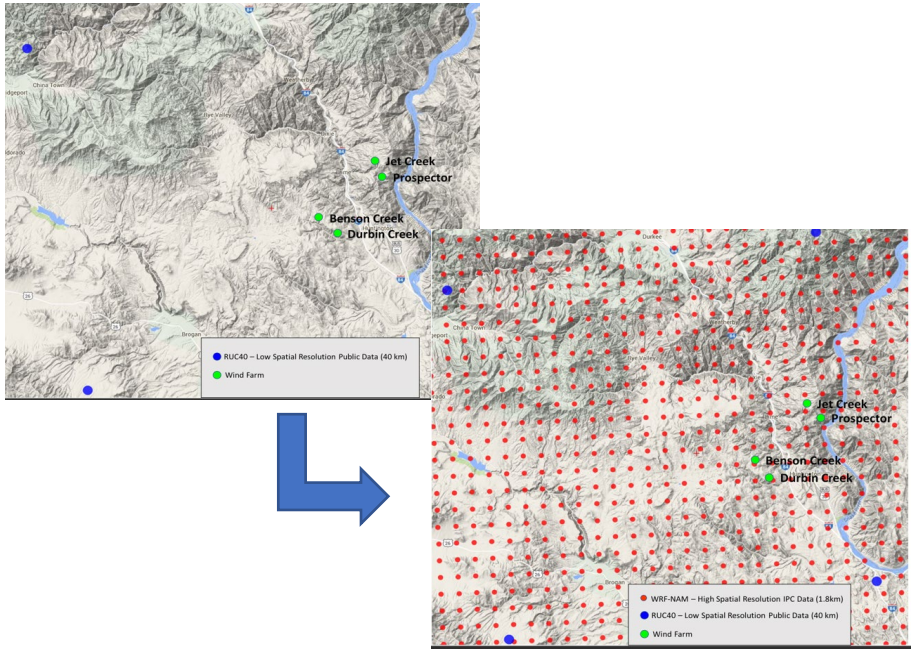
Sophisticated modeling technologies are necessary for:

- Planning & Development of new projects
- Forecasting & Guiding Operations
- Analysis

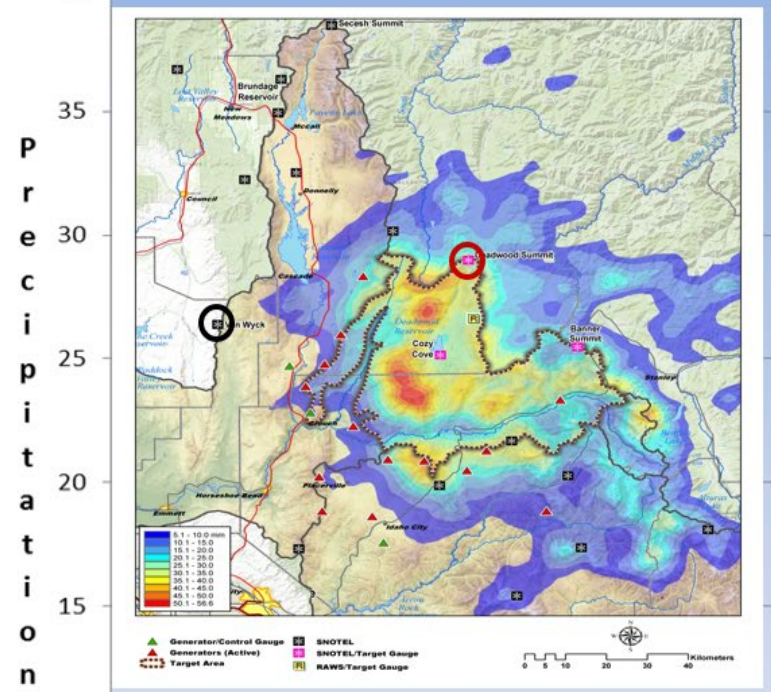


Weather Research & Forecasting (WRF) Models

- **WRF** | Designed for atmospheric research and operational forecasting
- National WRF model struggles to resolve mountainous terrain, need for development of region-specific model
  - ~40km grid size → 1.8km
- **WRF Cloud Seeding Model (WRF-WxMod)**
- **WRF Hydrologic Model (WRF-Hydro)**



WRF Model Forecast Versus Observed Precipitation



Computing

Lots of modeling = Lots of computing power

- High Performance Computing (HPC) is required to run sophisticated modeling technologies
- 2019 | IWRB & IPC Partnered w/Boise State University (BSU) and Idaho National Laboratory (INL) for purchase of the “Borah” HPC System
  - IPC/IWRB share computing space (CS Operations & Research)
  - Quickly outgrown → IWRB currently exploring options (cloud based, new equipment, leased space, etc)

Cloud Seeding Impacts Analysis

Objective: *Estimate how cloud seeding operations impact hydrology in the Payette, Boise, Wood, Upper Snake River Basins*

- Phase 1 (2019-2020)
  - Designed to approximate benefits to water use categories
  - Simplified analysis (No Operations Model)
  - Models "present conditions"
- Phase 2: RiverWare modeling (2020-Present)
  - Implements reservoir operations & calibrated hydrologic modeling
  - Groundwater and recharge feedbacks
  - Model sensitivity analysis – Testing the model

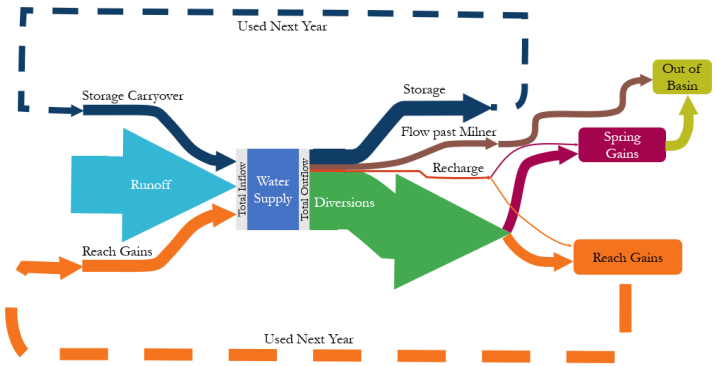
How much additional precipitation (%) was generated?

WRF-Hydro

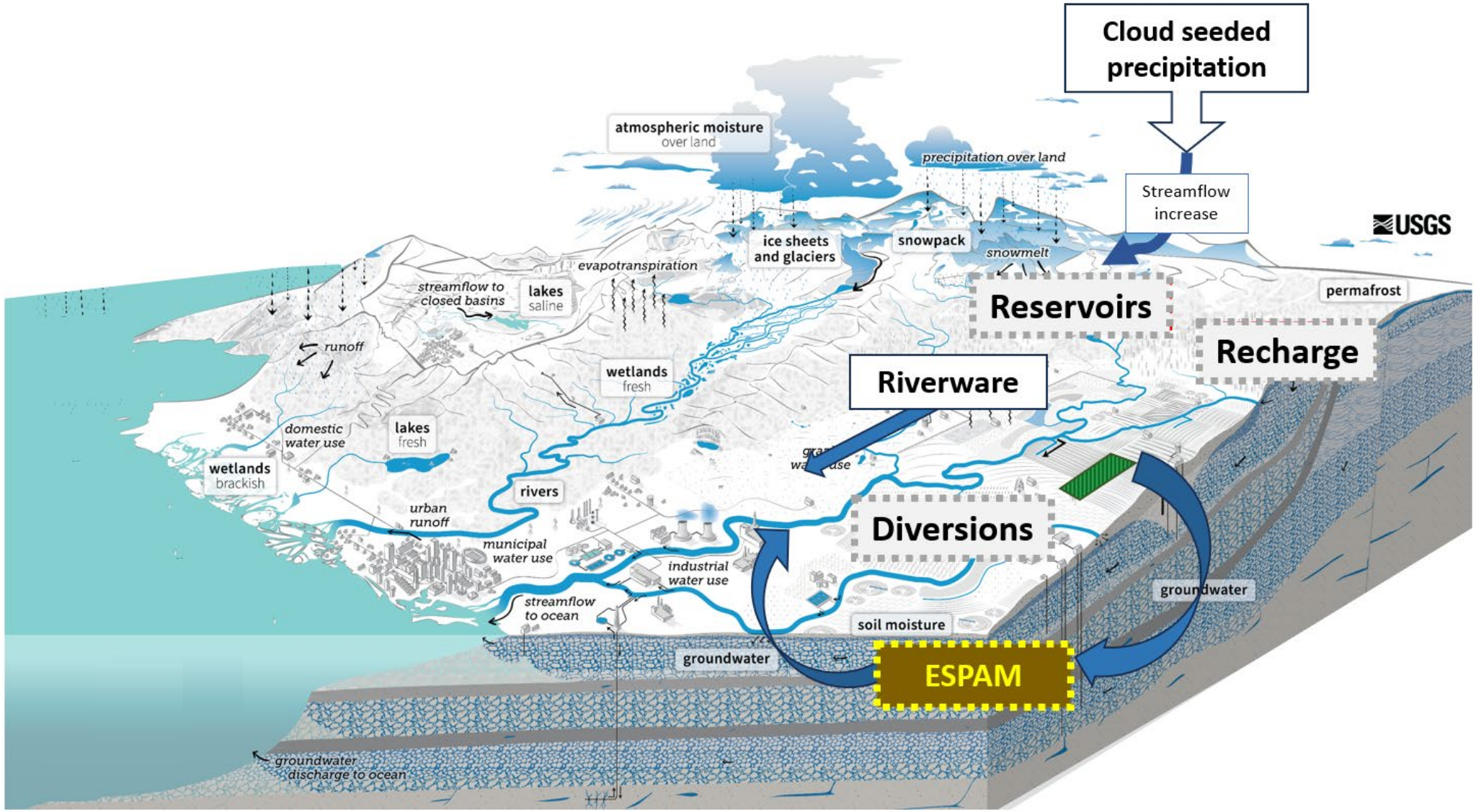
How does that translate to water on the ground?

RiverWare

How does the system change with increased supply?



Cloud Seeding Impacts Analysis



Cloud Seeding Impacts Analysis (Next Steps)

How much additional precipitation (%) was generated?

WRF-WxMOD*
(WRF Cloud Seeding Model)

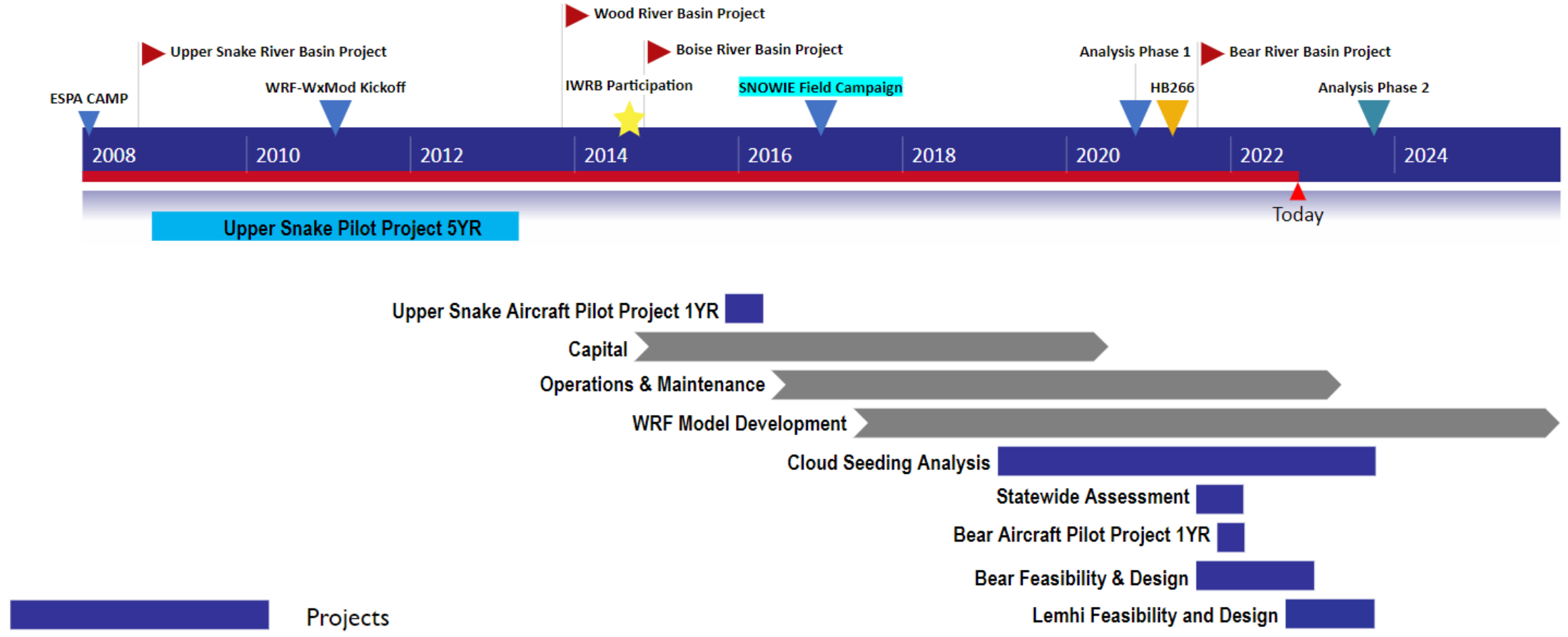
How does that translate to water on the ground?

- Targeting WRF-Hydro for more seamless integration with WRF & WRF-WxMod
- Other hydrology models could be considered

- Initial Snake River model developed by USBR for Columbia River planning purposes
- Collaboration between IDWR and IPC to update model with new improvements
- Improvements include:
  - Reservoir operations
  - Groundwater response
  - Diversions
  - Flow augmentation
  - Recharge
- Requires sensitivity analysis to understand how model responds to basic inputs

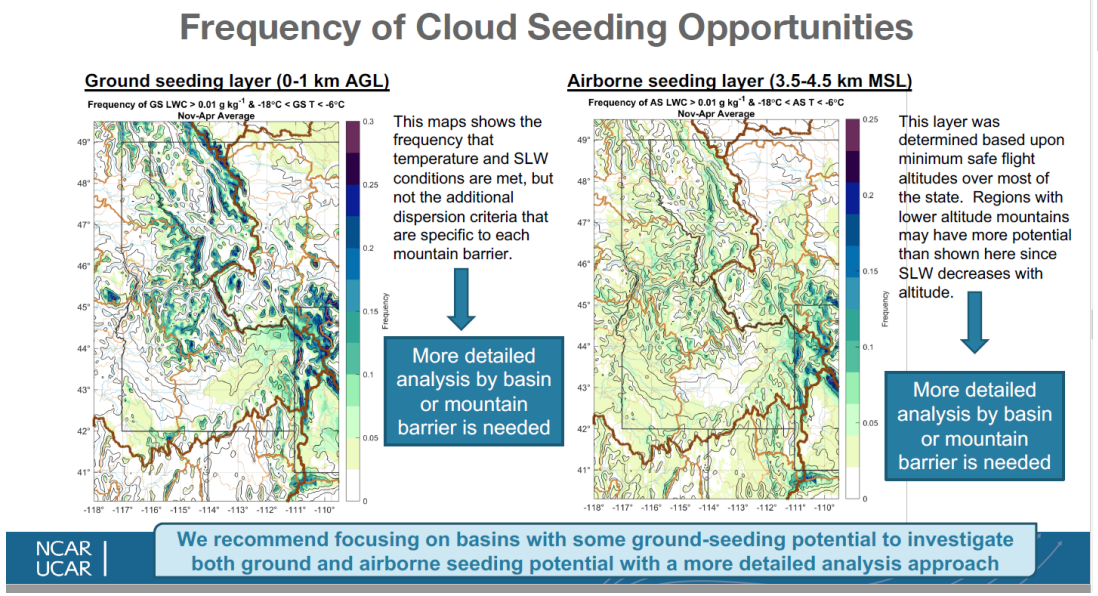
Currently still in development for this use of the model*

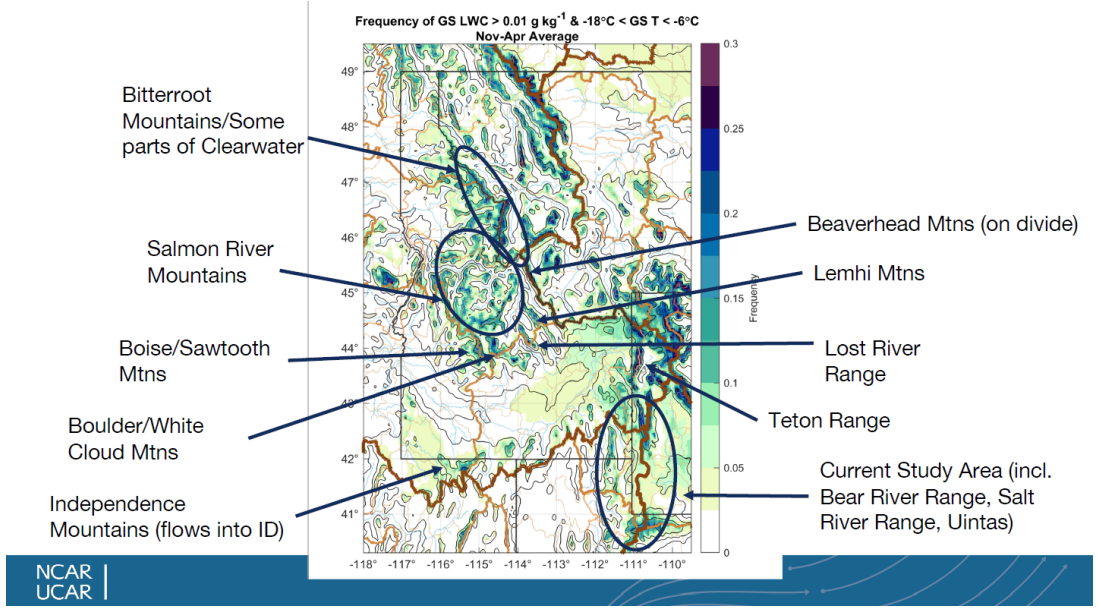
Idaho Cloud Seeding Program Development



Statewide Assessment

- July 2021– Contracted with the National Center for Atmospheric Research (NCAR) to look at opportunities for cloud seeding across the State of Idaho
- Provides initial look, more detailed feasibility required for basins of interest
- Looks for ground and airborne seeding opportunities (AgI)
- Opportunities for seeding with propane
- $30,000 Project Cost





Feasibility & Design Studies

Current Investigations:

- Bear River Basin, Completed Dec 2022 |
  - Includes investigation of opportunities for shared infrastructure w/ Upper Snake River Basin
  - Results presented to IWRB Sep 2023 → IWRB working to determine next steps
- Lemhi River Basin, *est completion* Sep 2024 |
  - Includes Cost/Benefit Analysis
  - Potential shared infrastructure w/State of Montana

Research & Development

Current Efforts

Seeding Agents

- **Liquid Propane (LP) Research** | LP has been demonstrated to nucleate ice in lab settings at warmer temperatures than AgI and at a reduced cost– *Can LP be used to effective seed clouds in an operational setting?*
  - Working towards development of a comprehensive investigation (similar to SNOWIE and AgI)
  - Winter 2022-2023 field investigations
  - Winter 2023-2024 field investigations
  - LES Modeling
  - Identifying project partners

Instrumentation

- **SWEdar Development** | Gaps in available weather data contribute to reduced efficiency in planning, operations, and analysis. Implementation of SNOTEL sites is expensive and difficult to implement.
  - Potential "Micro-SNOTEL" sites will provide necessary data at reduced cost and with reduced footprint

IWRB Cloud Seeding Program Budget | FY2024

CLOUD SEEDING PROGRAM			
			FY24 Approved
Operations & Maintenance	**Collaborative Program**	(B/W/US) 2023-2024 operations; IWRB cost share 2/3 Program Total	$2,300,000
	Bear River Basin	N/A for 2023-2024 operations	$0
	Technology	Model and computing administration, device support	$50,000
		TOTAL	**$2,350,000**
Capital	**Weather Instrumentation**	Replacement/Enhancement/Upgrade, existing	$200,000
		New Devices (statewide)	$1,000,000
	Modeling	Modeling, computing, device support	$1,000,000
	Infrastructure	Equipment for new basins (Bear/US shared/Lemhi/Other… for season Nov 2024-25)	$750,000
		TOTAL	**$2,950,000**
Research & Development	**Technology**	Development of instrumentation and modeling, data support	$0
	Investigations	Analysis, assessments, cost share in research to support policy questions	$1,000,000
	Reserve	Additional Program Costs	$700,000
		TOTAL	**$1,700,000**
CLOUD SEEDING PROGRAM TOTAL			**$7,000,000**

Program Priorities & Next Steps

- **Develop Program Structure**– *What is the State's roll? The roll of stakeholders?*
- **Secure long term collaborative agreements**– *How will the program be funded long term?*
- **Assess opportunities for program expansion or enhancement**– *Can we grow the program/be more effective? How can we support other regions of the state?*
- **Ongoing monitoring and analysis**– *How will we ensure the programs continued effectiveness (validation)? How will we address public concerns regarding environmental considerations or extra area effects?*
- **Research and Development**– *How will we support policy questions? How will we fund R/D? Who are other potential partners?*

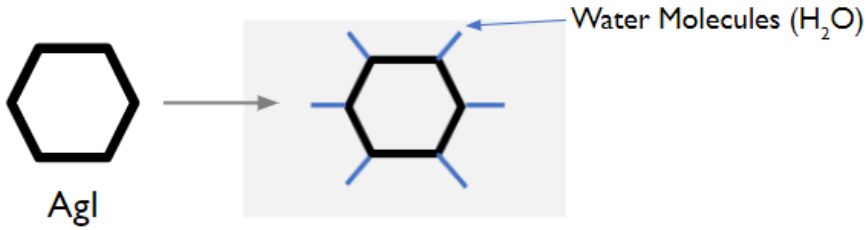
Frequently Asked Questions

- Is Cloud Seeding Safe?
- Are we “Robbing Peter to Pay Paul” or having “downwind effects”

Environmental Topics

What is Silver Iodide (AgI)?

- Inorganic compound
- Inert in the *natural* environment
  - Insoluble in water → can't become free silver available to aquatic organisms
  - Solubility close to that of Quartz (white sand)
- Similar hexagonal structure as naturally forming ice crystals



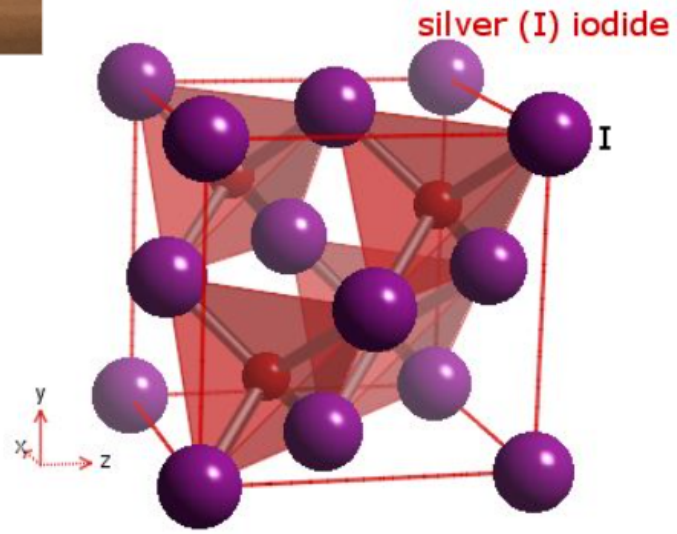
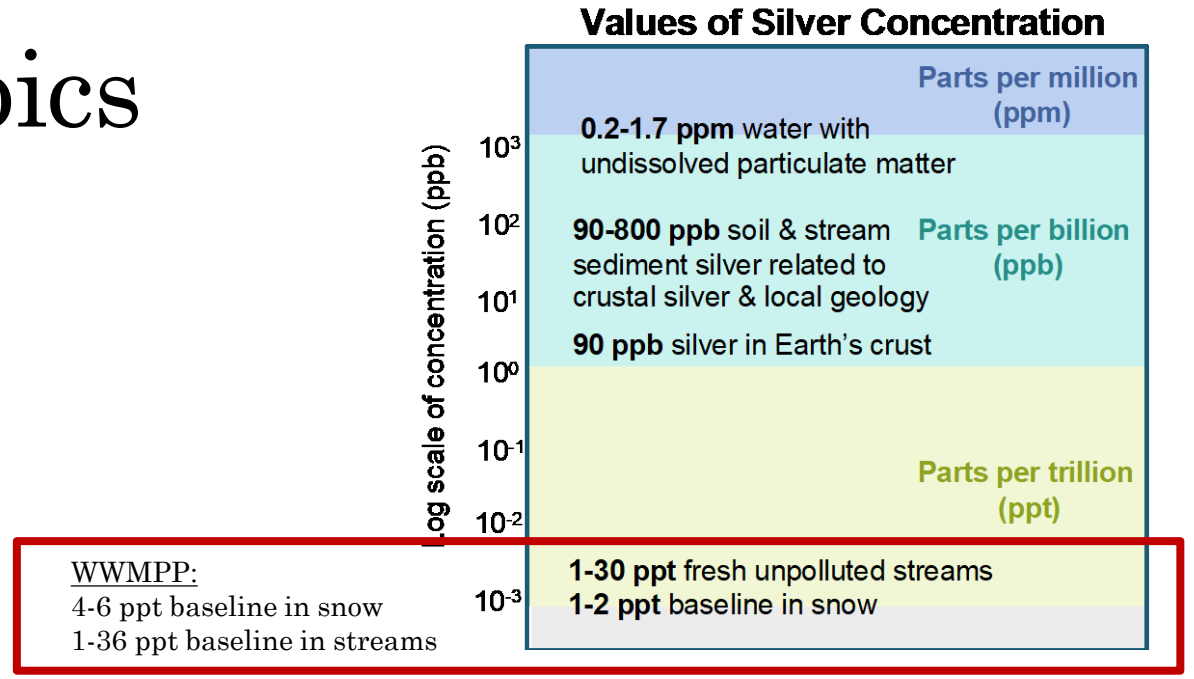


Image Courtesy of WebElements.com

Environmental Topics

- Trace chemistry analyses of snow, water, and soil samples have shown a **negligible environmental impact from seeding operations**
- Trace chemistry measures amounts of chemicals in such small concentrations that clean gear and clean procedures are required
- Localities exceeding these concentrations tend to be a result of anthropogenic releases (mines, photographic industry, urban refuse combustion, sewage treatment facilities).



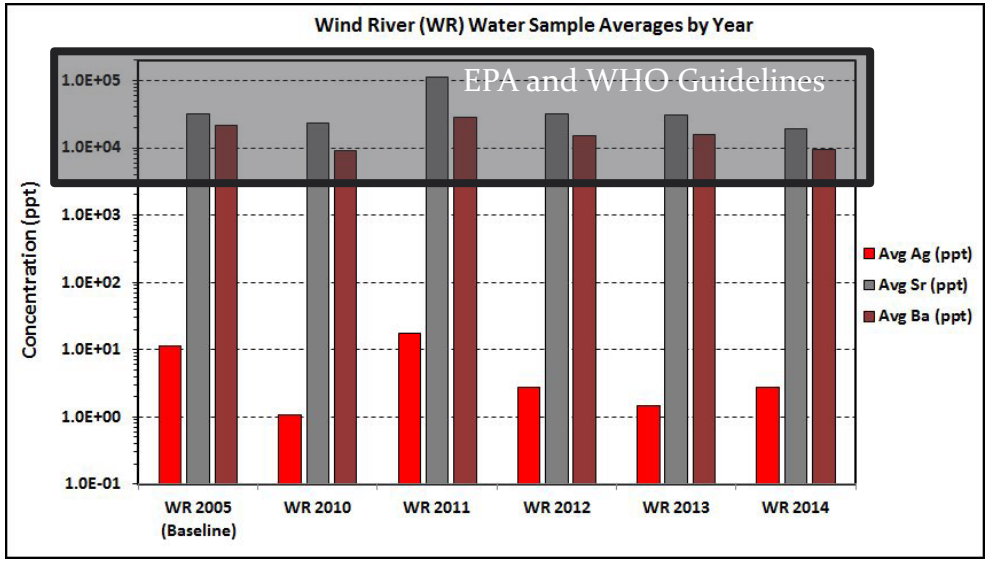
Far less than would be expected from other (background) sources of silver

Images/Table/Figures Courtesy of Heritage Environmental

Environmental Topics

- Total silver in water measured during seeding operations was the same order of magnitude as the baseline from years before seeding started.
- Several orders of magnitude less than values considered hazardous to the environment or human health.

Silver in Water Samples from WWMPP



From the WWMPP

Figures Courtesy of Heritage Environmental

“Downwind Effects”

How much water are we talking?

- Clouds form when invisible water vapor in the air condenses into visible water droplets or ice crystals

- Nature will condense roughly 20% of the total available water vapor as moist air rises over a mountain barrier

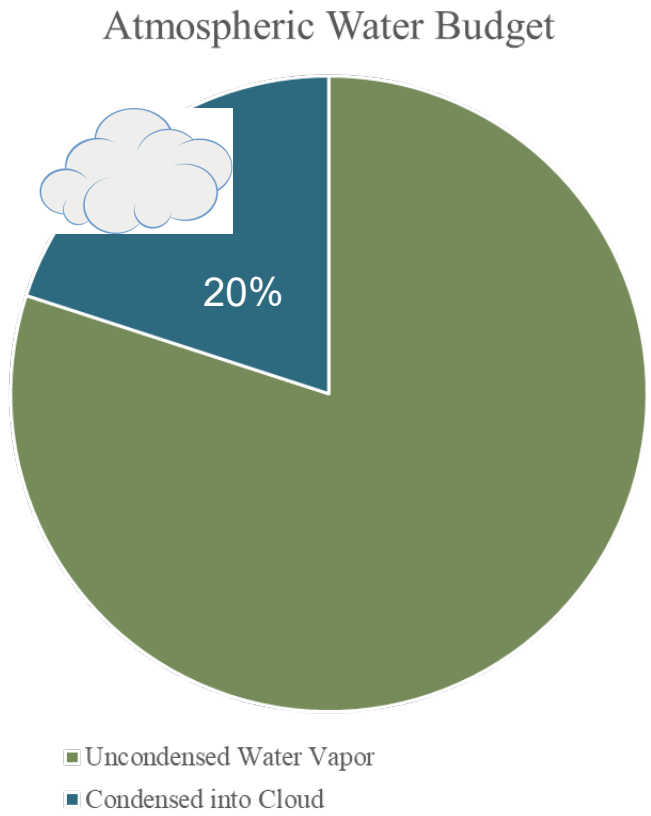


Figure Courtesy of Idaho Power Company

“Downwind Effects”

How much water are we talking?

Winter storms are typically about 30% efficient →

*“only **30%** <u>of</u> that total **20% condensed water vapor** will fall to the ground as precipitation, roughly equal to 6% of the total water content”*

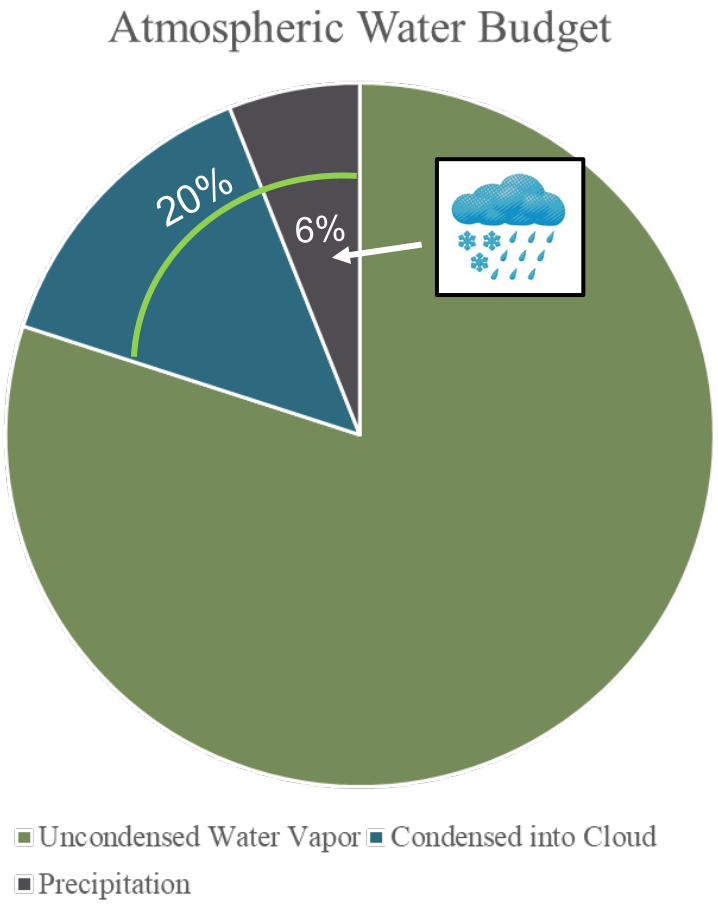


Figure Courtesy of Idaho Power Company

“Downwind Effects”

How much water are we talking?

Cloud seeding enhances the storms efficiency →

*“with cloud seeding there could be **~10-15% more** (on average) <u>of</u> that **20% condensed water vapor** hitting the ground as precipitation; an increase of <1% from the total water content”*

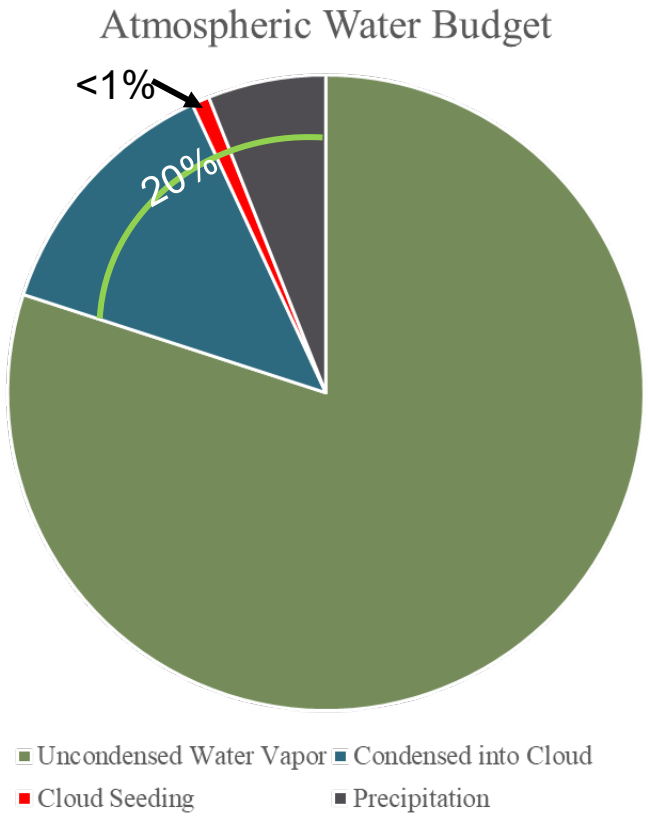


Figure Courtesy of Idaho Power Company

“Downwind Effects”

Are we “Robbing Peter to Pay Paul,” or taking water from downwind users?

- Consider that an atmospheric river is very dynamic, and, like a surface flowing river, also has many gains and losses as it moves across the continent
- Factoring the amount of overall water content “diverted” through seeding, and the average rate of resaturation, it is unlikely to see negative impacts to downwind basins
- It is more likely that there are ***benefits*** to downwind basins, as the nucleation process in a seeded cloud can continue for a given distance downwind of the target basin → aiding downwind precipitation as a result.
- Further research is required to better address this question

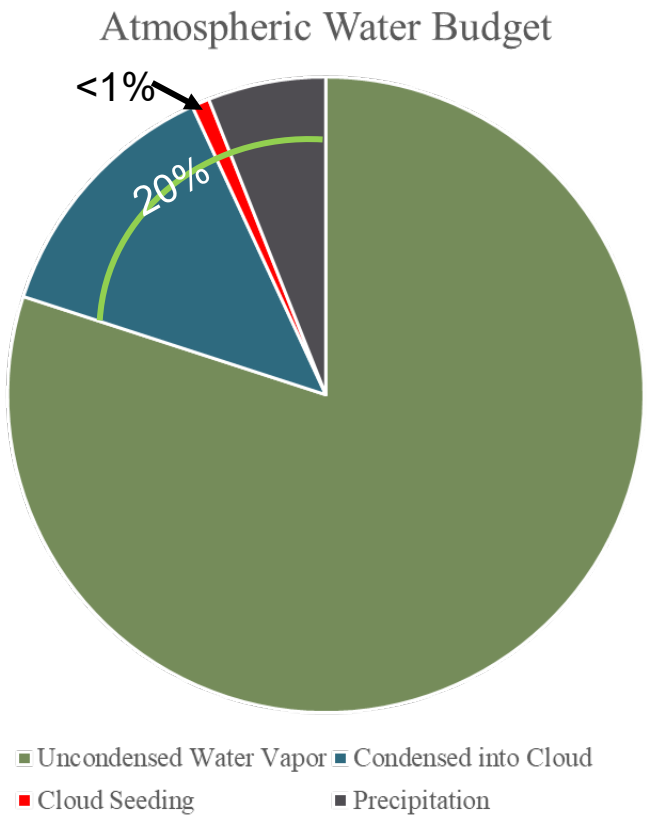


Figure Courtesy of Idaho Power Company

Questions?