Estimating the Climate Resiliency of WA Dairy Farms

Michael Lowry

WSDA Nutrient Management Technical Services

5/21/2026

About Me

- Joined NMTS November 2024
  - Sole GIS employee
- Yakima
- Former U.S. Forest Service botany technician
  - 2014-2024

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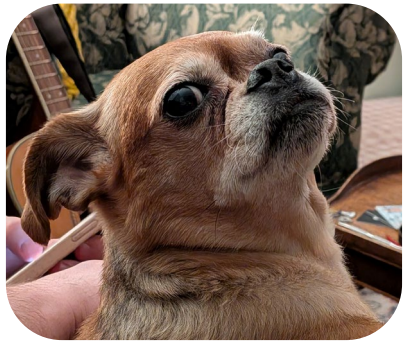
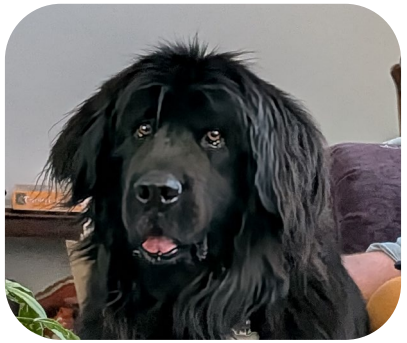




Topics

- Background
- Data Sources
- Data Processing
- Report Design
- Meeting with Farmers
- Coding Lessons

Background

Background
NMTS

- Nutrient Management Technical Services
  - (Dairy Nutrient Management Program)
- Goal
  - Proper manure containment & application
  - Protect surface water, groundwater
- Compliance
  - Regular on-site inspections
  - Enforcement
- Technical Assistance
  - Guidance, resources

Background NMTS

Kyrre Flege
Program Manager

Michael Isensee
Operations & Compliance Supervisor

Amanda Hendrix
Water Quality Project Inspector

AJ Mulder
SW Region Specialist

OB Sheriff
Ground Water Management Area Specialist

Jera Monaghan
Nutrient Management Specialist

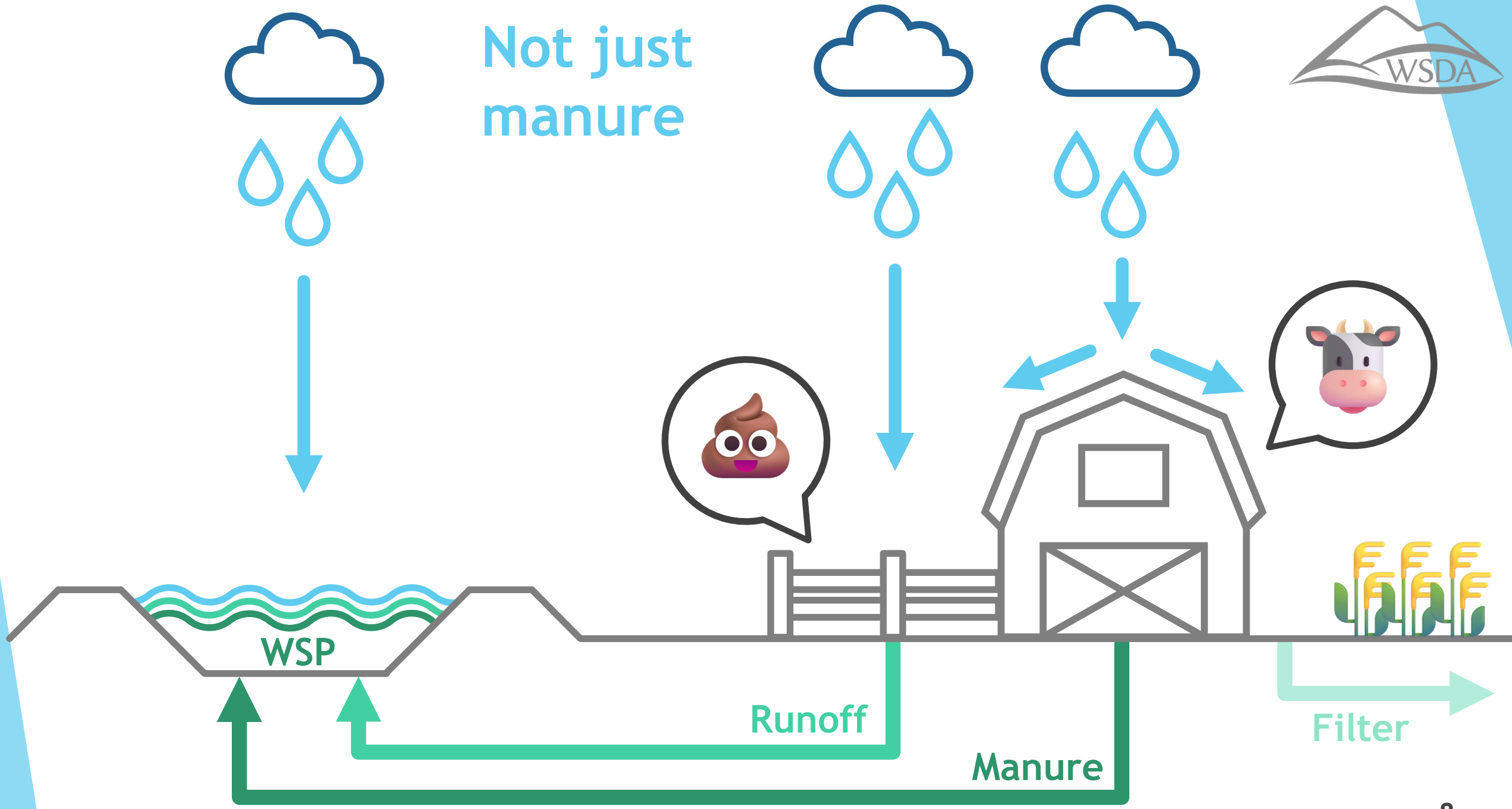
Liz Whitefield
Outreach Specialist

Kevin Huynh
Data Consultant

Background
Dairy Farms

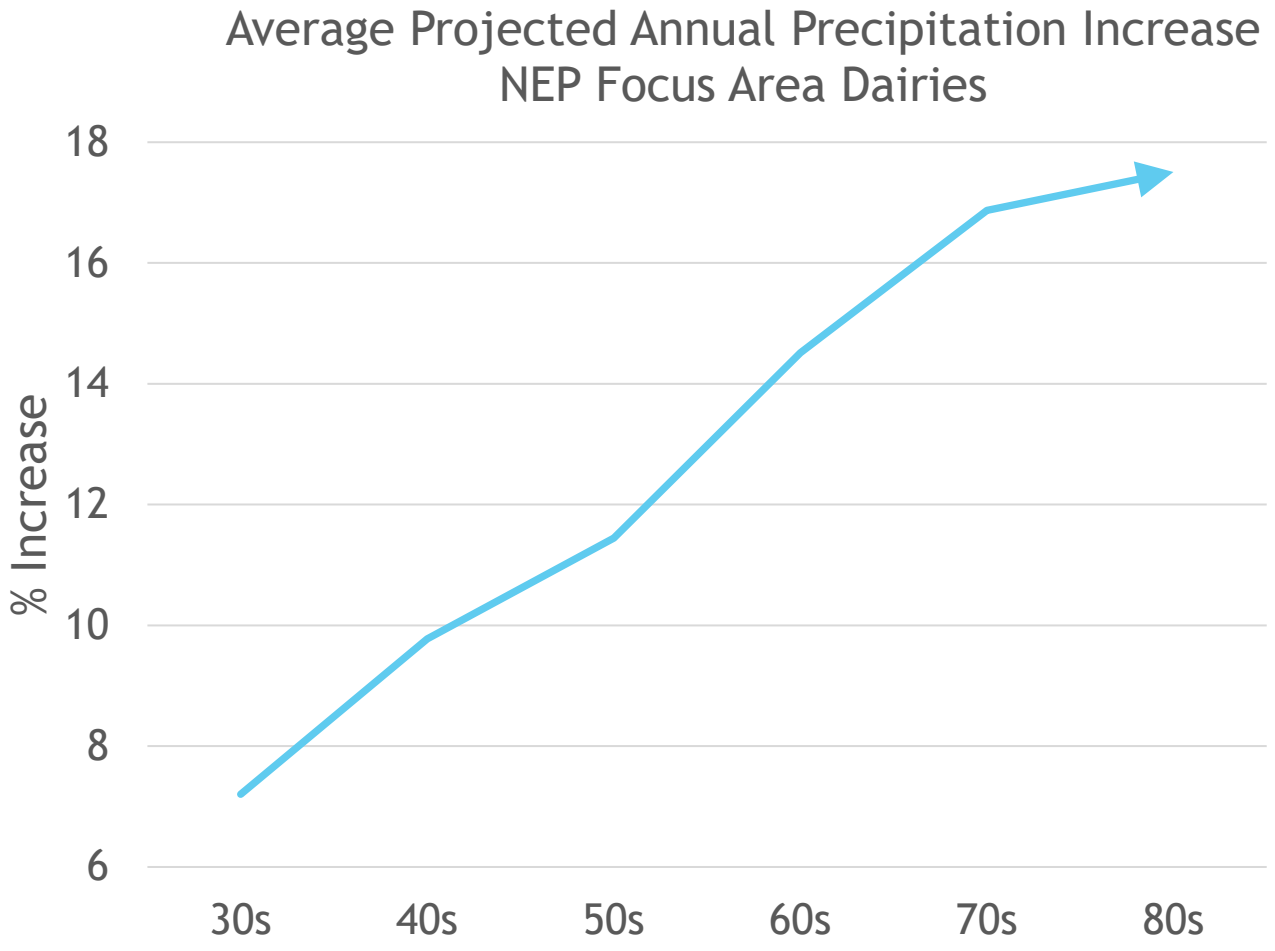
- Store manure in waste storage ponds
- Apply manure from ponds to fields
- Application restrictions
  - Runoff risks
- Wet Season: Oct-Mar
  - Can’t apply the manure
  - Rain & manure fill the ponds
  - Overtopping risk

Not just manure



Background
Climate Change

- Climate models:
  - Increase in precipitation
- More water in storage ponds
- Are dairies prepared?
  - Additional volume



Compared to 1980-2009 data

Climate Mapping for a Resilient Washington

Climate Impacts Group

University of Washington

Background
NEP Grant

$1.5 million grant (2023)

From	Environmental Protection Agency
For	Puget Sound National Estuary Program
To	**Reduce manure-based contamination**
By	**Evaluating climate-resiliency of dairy infrastructure**

Background
The Project

Evaluating climate-resiliency of dairy infrastructure

Background
The Project

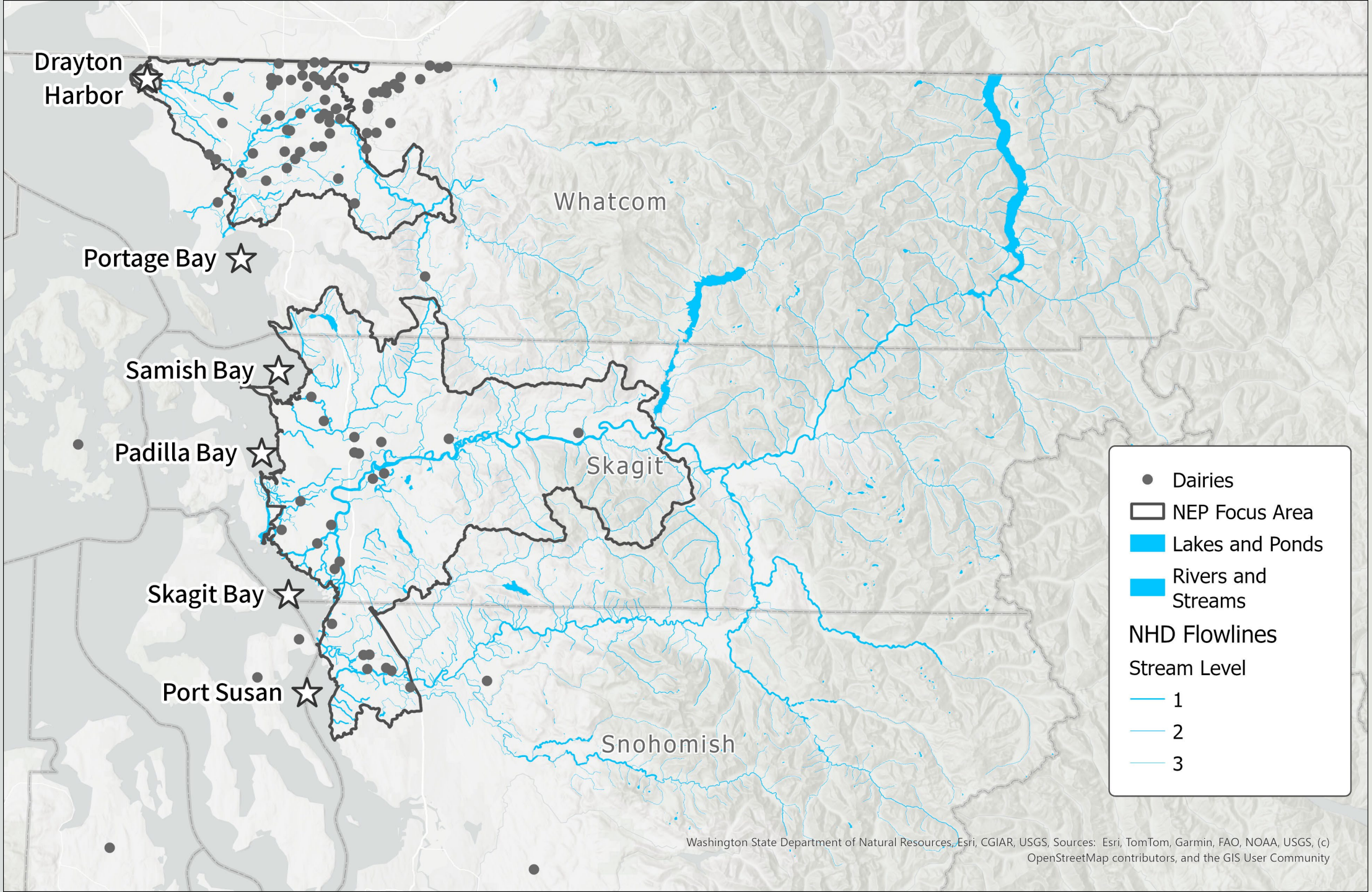
Evaluating climate-resiliency of dairy infrastructure

- How much wastewater?
- How much increase?
- Storage capacity?

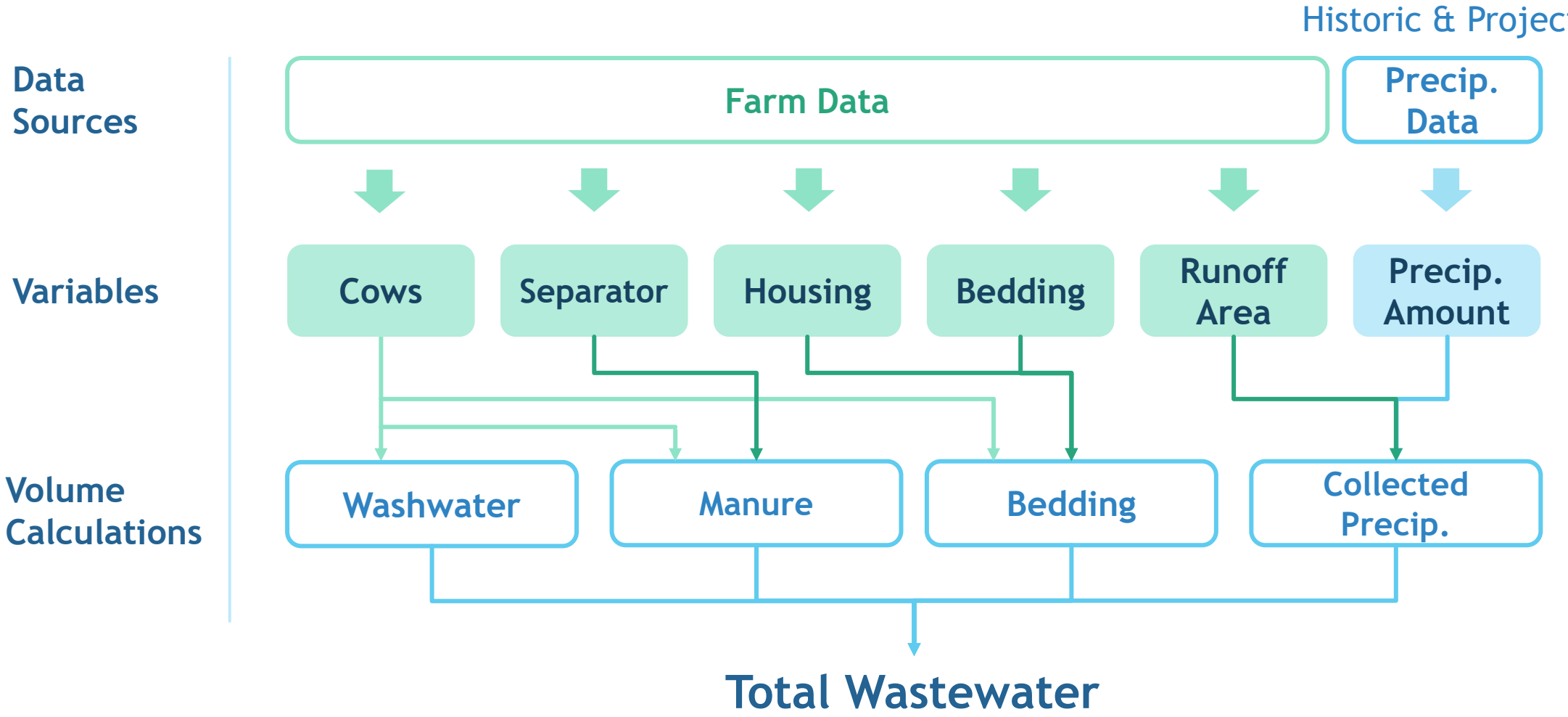
Background
The Project

Evaluating climate-resiliency of dairy infrastructure

- Ask
- Visit farms
- Analyze data
- Create reports for farmers
- Have conversations
  - Recommendations
  - Technical assistance


Drayton Harbor
Portage Bay
Samish Bay
Padilla Bay
Skagit Bay
Port Susan
Whatcom
Skagit
Snohomish
Dairies
NEP Focus Area
Lakes and Ponds
Rivers and Streams
NHD Flowlines
Stream Level
1
2
3
Washington State Department of Natural Resources, Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community

Background
Estimating Wastewater

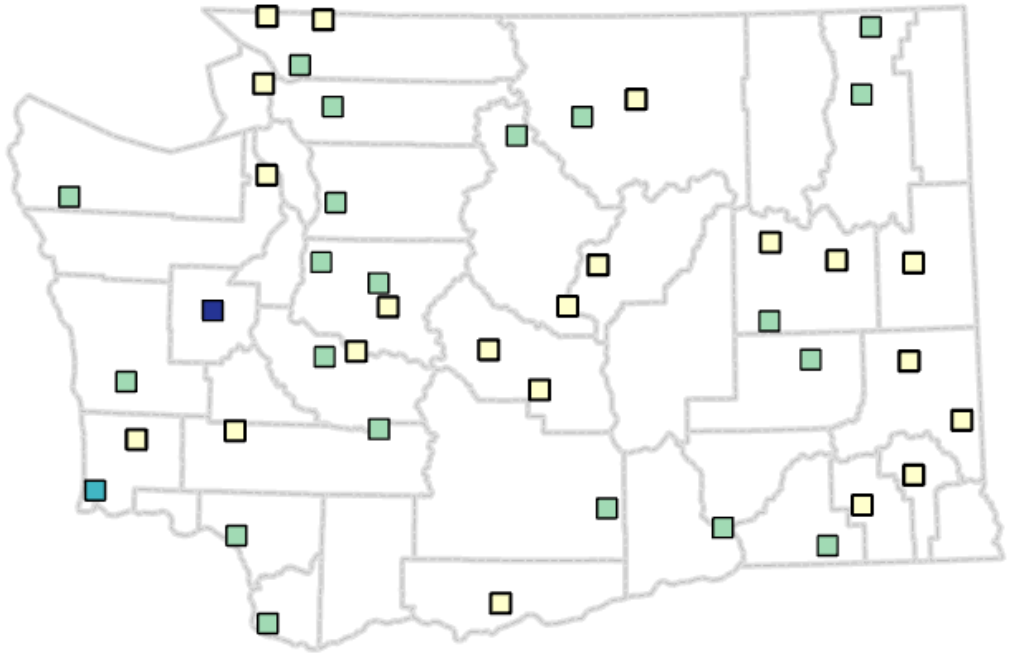


Data Sources

Data Sources
Historic Precipitation

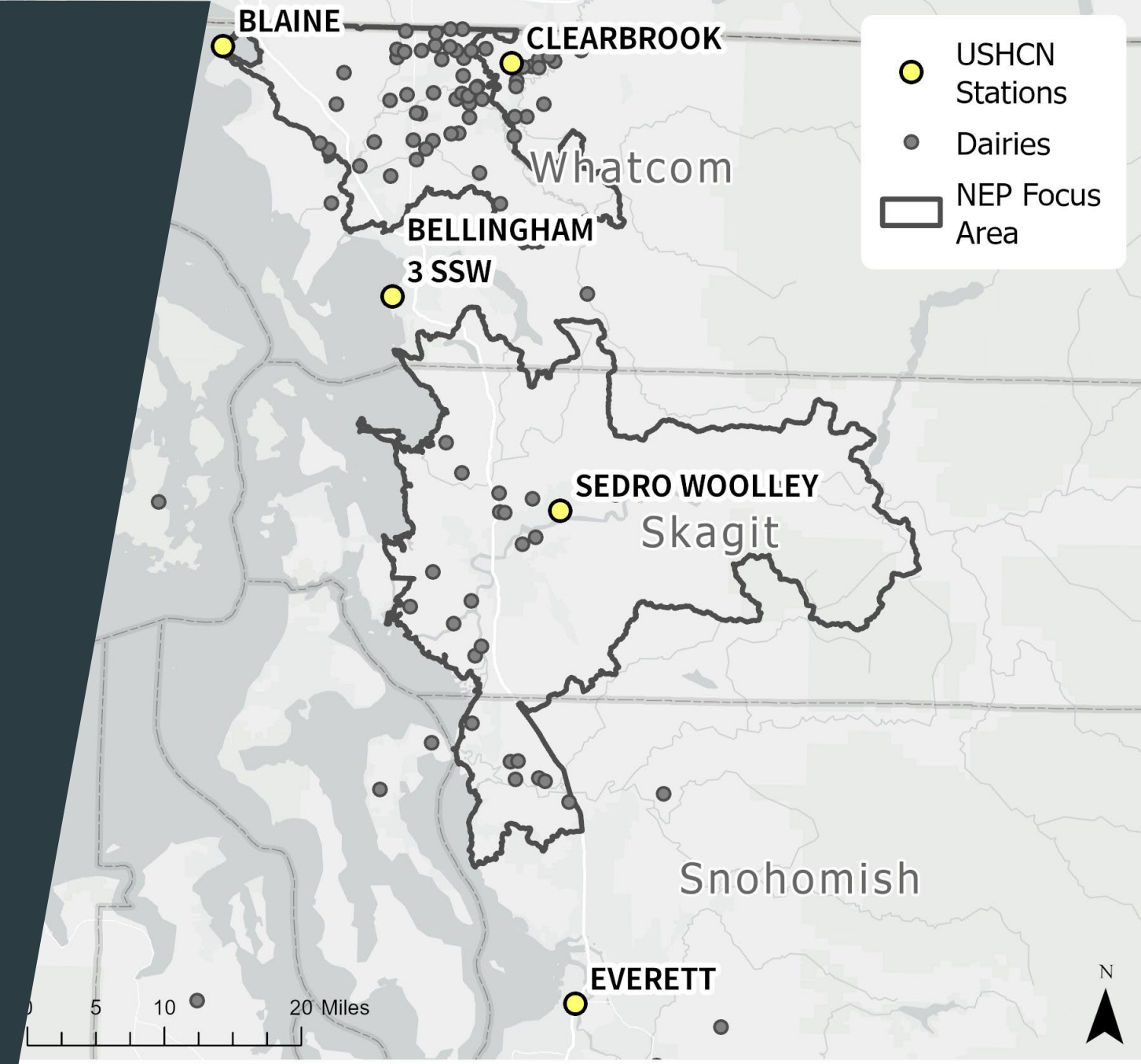
- U.S. Historical Climatology Network (USHCN)
  - Long-term, quality data
  - Monthly precipitation
  - 44 weather stations in WA

U.S. Historical Climatology Network (USHCN)



Data Sources
Historic Precipitation

- 5 stations in/around focus area



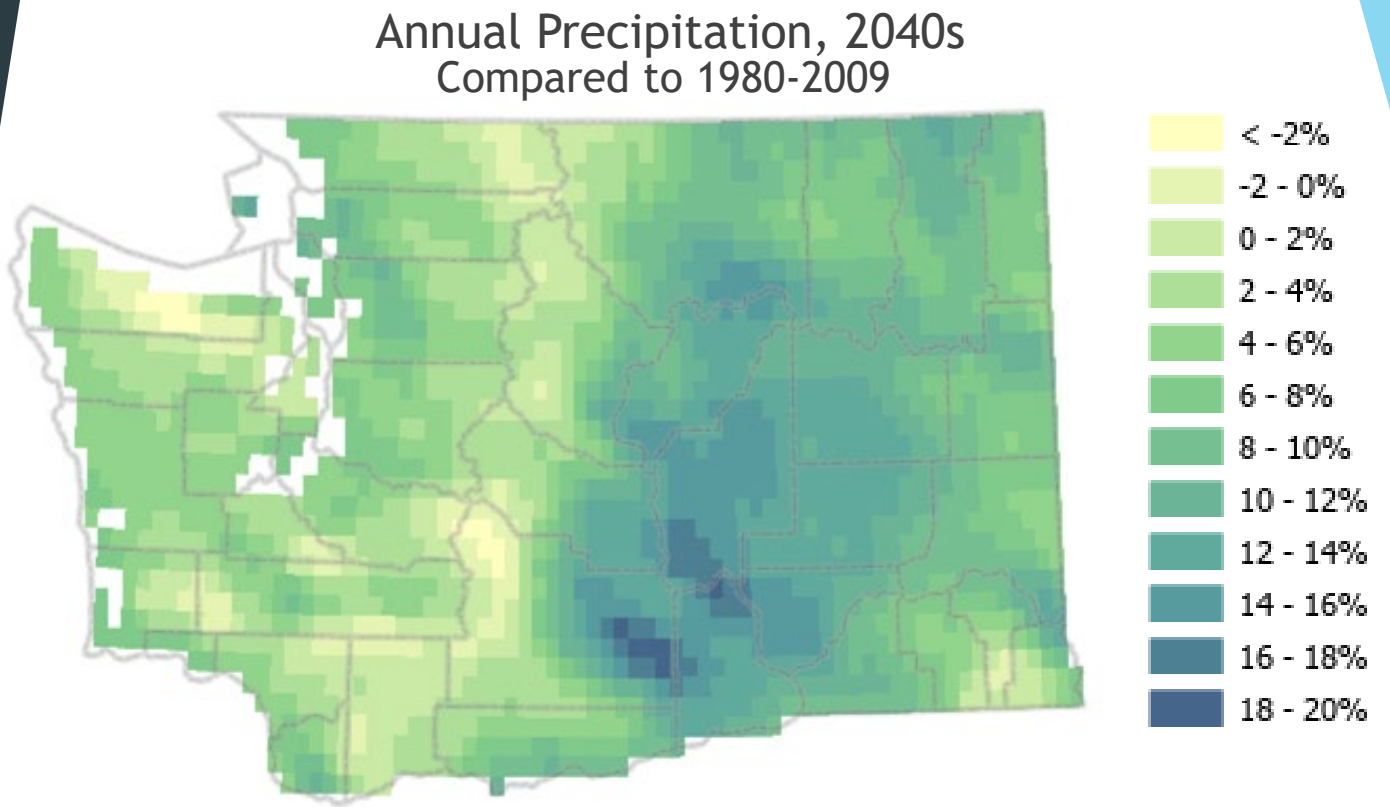
Washington State Department of Natural Resources, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community

Data Sources
Projected Precipitation

- Precipitation projections:
  - Annual
  - Late Summer
  - Heavy Events
  - Extreme Events
  - 1- 2- & 3-Inch Days
- Time periods:
  - 2030s, 40s, 50s, 60s, 70s, 80s

Climate Mapping for a Resilient Washington

Climate Impacts Group, UW



WSDA

CLIMATE IMPACTS GROUP

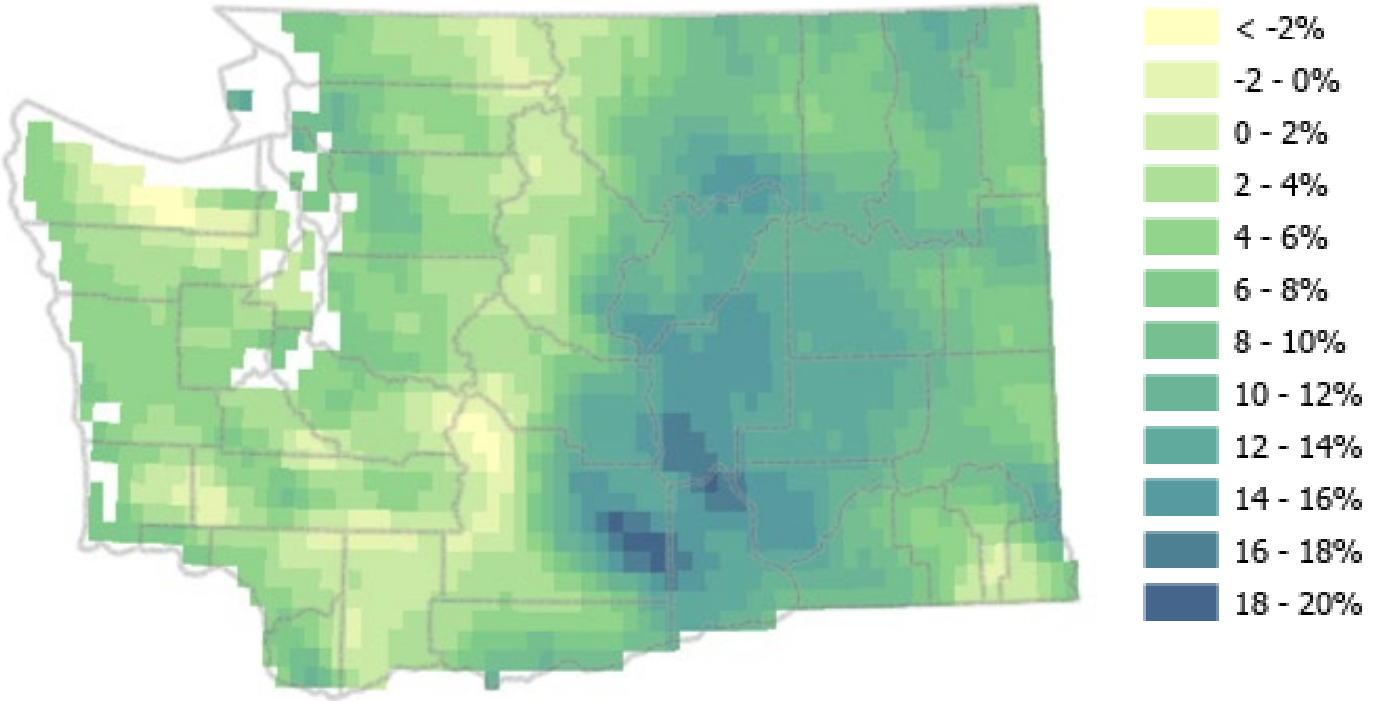
Data Sources
Projected Precipitation

- Resolution: 12km x 12km
- High emission scenario (RCP 8.5)

Climate Mapping for a Resilient Washington

Climate Impacts Group, UW

Annual Precipitation, 2040s
Compared to 1980-2009



WSDA

CLIMATE IMPACTS GROUP

Data Sources
Farm Data

- Dairy Infrastructure GIS Dataset
  - July 2025
  - Mapping what is inspected
    - Nutrient management
  - Surface area


Microsoft, Vantor


AB-02
AB-01
AB-03
AB-04
AB-05
AB-07
AB-06
AB-10
AB-08
AB-09
SLD-01
SLD-02
WSP-02
WSP-01
SHOP
BUNK-02
COSH-01
COLL-01
CVDP-01
BUNK-01
Microsoft, Vantor


AB-02
AB-01
WSP-01
WSP-02
SLD-01
SLD-02
AB-04
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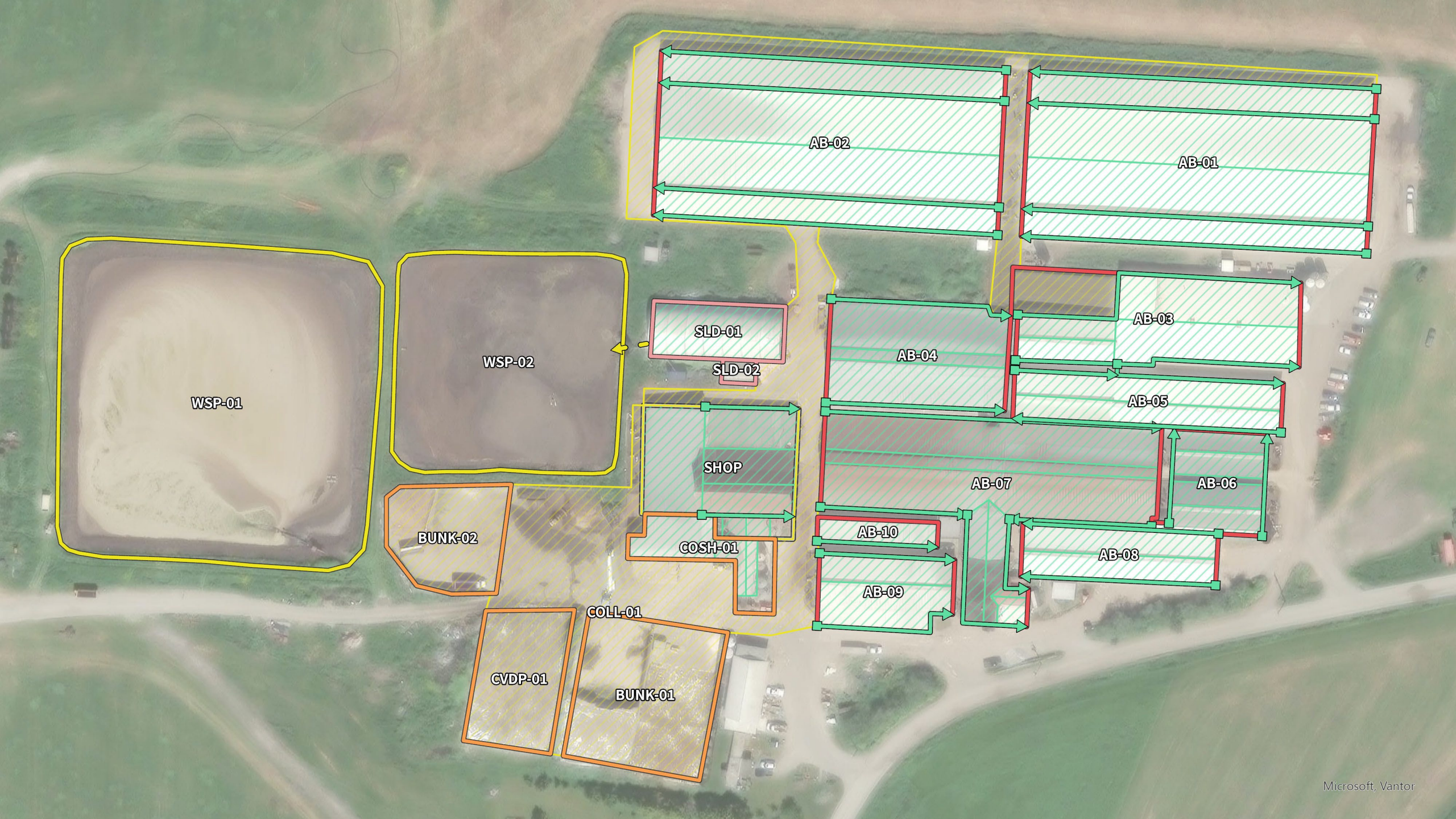
AB-02
AB-01
WSP-01
WSP-02
SLD-01
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AB-04
AB-03
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SHOP
AB-07
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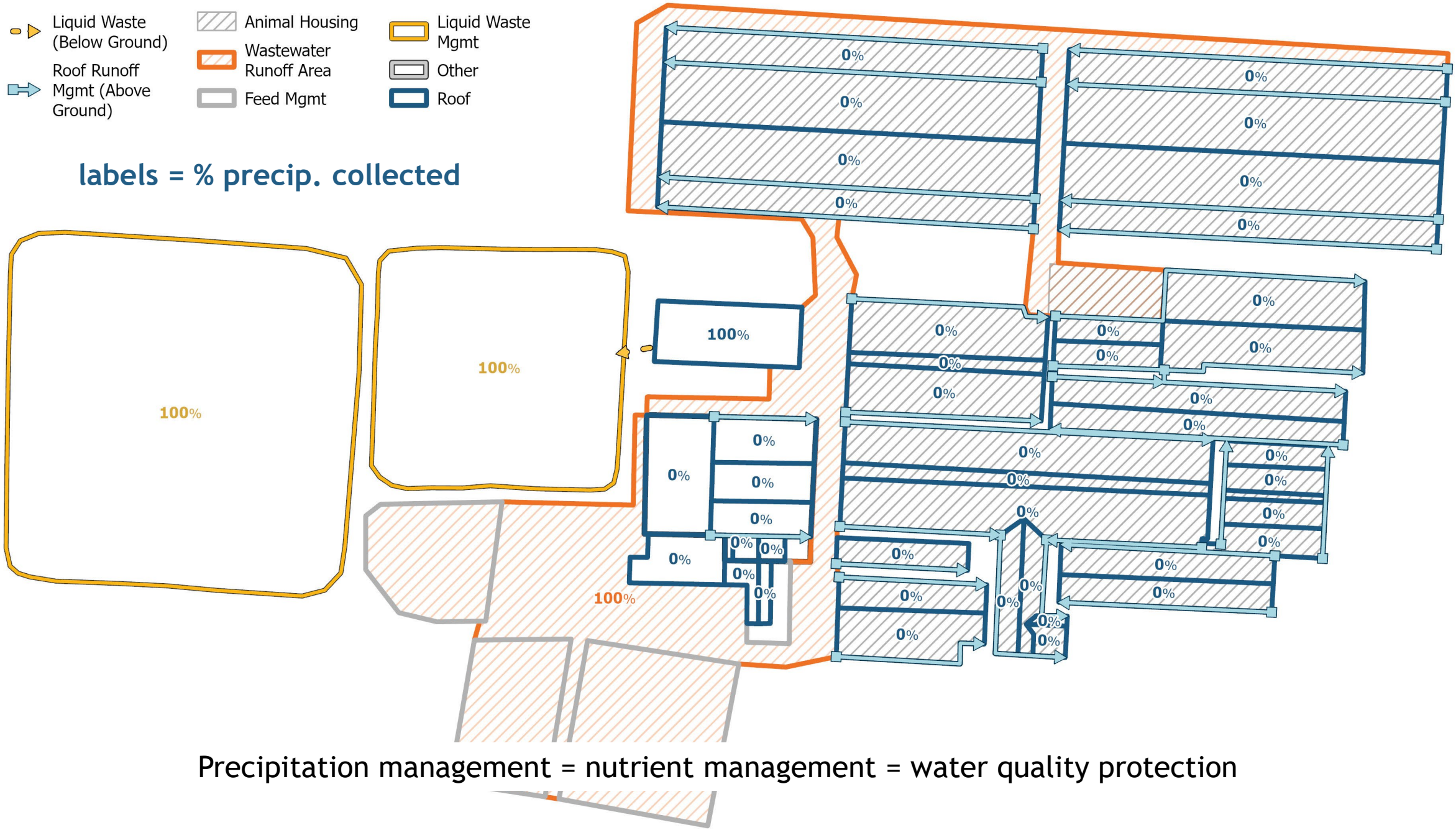
BUNK-01
Microsoft, Vantor



Precipitation management = nutrient management = water quality protection

Data Sources
Farm Data

- Farm Visits
  - Detailed information
  - Verify & complete GIS infrastructure data

Cows	numbers	breeds	weights
Separator	presence	efficiency	
Housing	type	waste management	
Bedding	material		
Runoff Area	map	percent collected	

Data Sources
Farm Data

- 3 inspectors
- 34 farms visited
- 4 months
- 1,600 polygons
- 600 lines
- 100 points

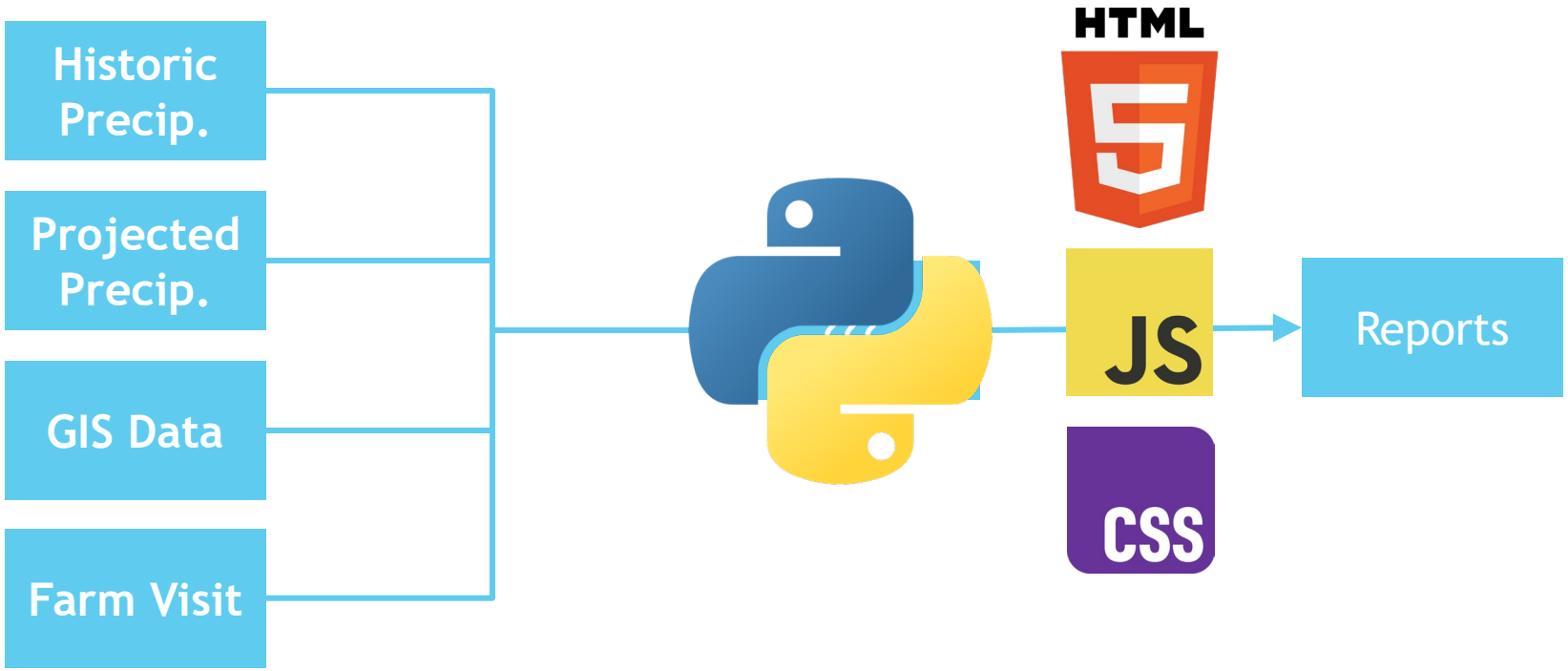
Amanda

AJ

Jera

Processing the Data

Processing the Data



Processing the Data

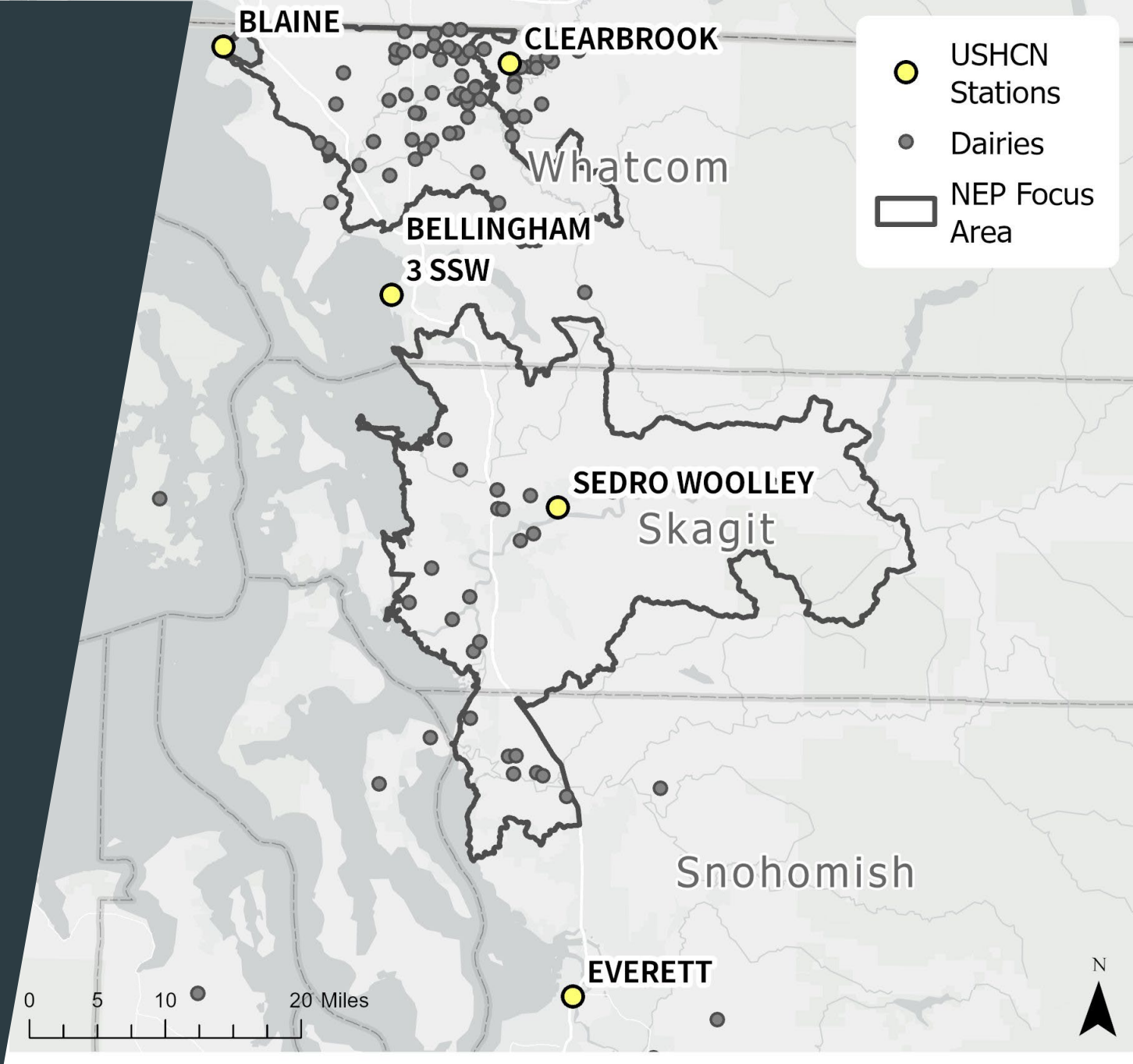
python™ modules

pandas	data manipulation
ArcPy	data manipulation
Rasterio	raster manipulation
matplotlib	charts
NumPy	trend lines

Processing the Data
Historic Precipitation

U.S. Historical Climatology Network

- Tasks
  - Parse downloaded data
  - Monthly -> Annual
  - Monthly -> Seasonal
  - Trends
  - Graphs



Washington State Department of Natural Resources, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community

Processing the Data
Historic Precipitation

- Calculate seasonal precipitation

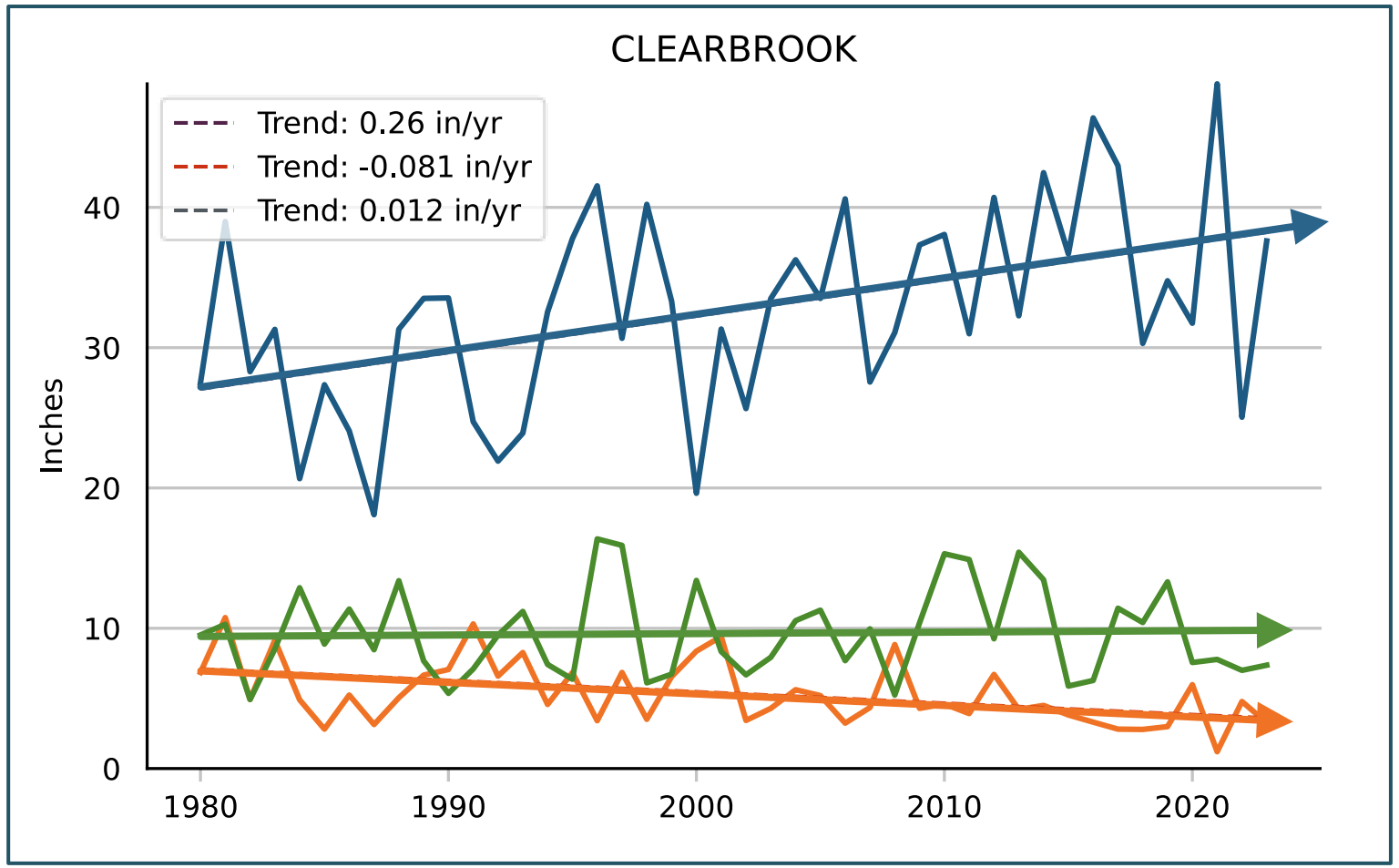
ArcPy **SearchCursor**
ArcPy **InsertCursor**

- Calculate seasonal trends
  - Change in inches per year

NumPy **polyfit()**

Processing the Data
Historic Precipitation

- Seasonal graphs
  - **matplotlib**



Menne, Williams and Vose. *The United States Historical Climatology Network Monthly Temperature Data Version 2.*

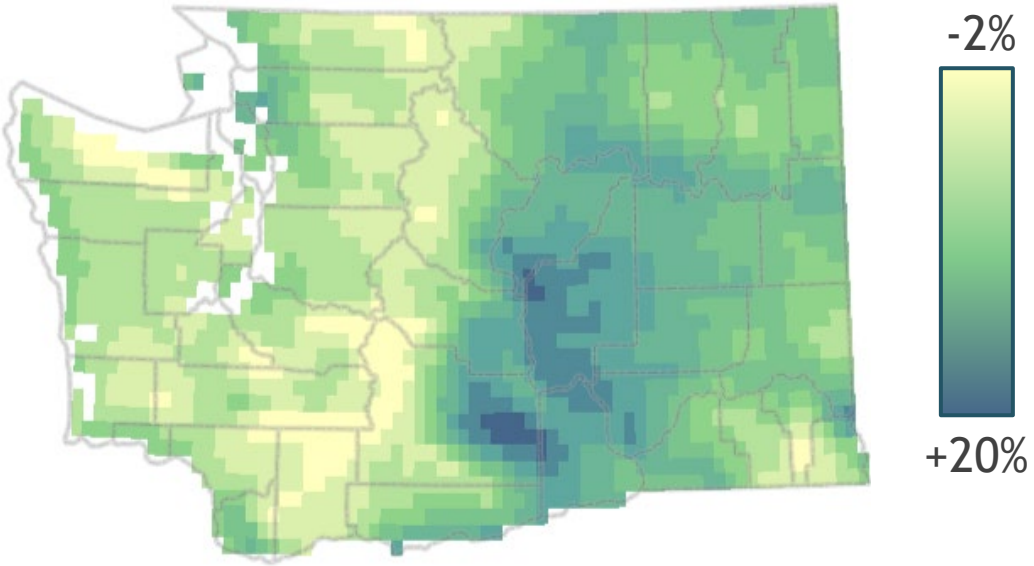
Processing the Data
Projected Precipitation

- Tasks
  - Extract data for each dairy
  - Graphs for each dairy

Climate Mapping for a Resilient Washington

Climate Impacts Group, UW

Change in Annual Precipitation, 2040s
Compared to 1980-2009



Precipitation Metrics

Annual	Heavy Event	1-Inch Days
Late Summer	Extreme Event	2-Inch Days
		3-Inch Days

Processing the Data
Projected Precipitation

- **Rasterio** library
  - Find values at dairy locations
  - 42 raster files
  - 230 dairies (entire state)
  - 9,660 values

Rasterio open() – open raster file
Rasterio read() – load raster data
Rasterio index() – find dairy point row/col

Processing the Data
Projected Precipitation

- Graphs
  - **matplotlib** library

Annual

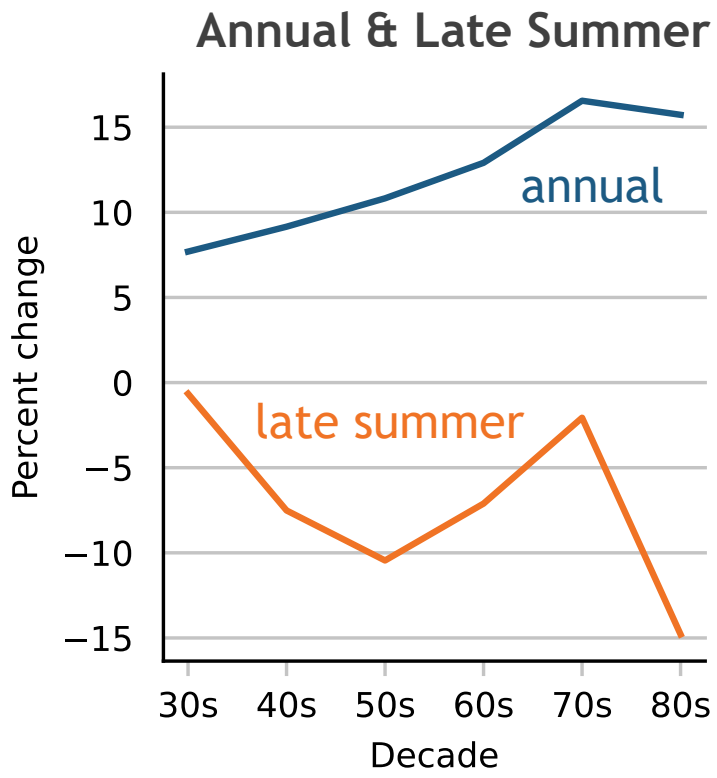
Heavy Events

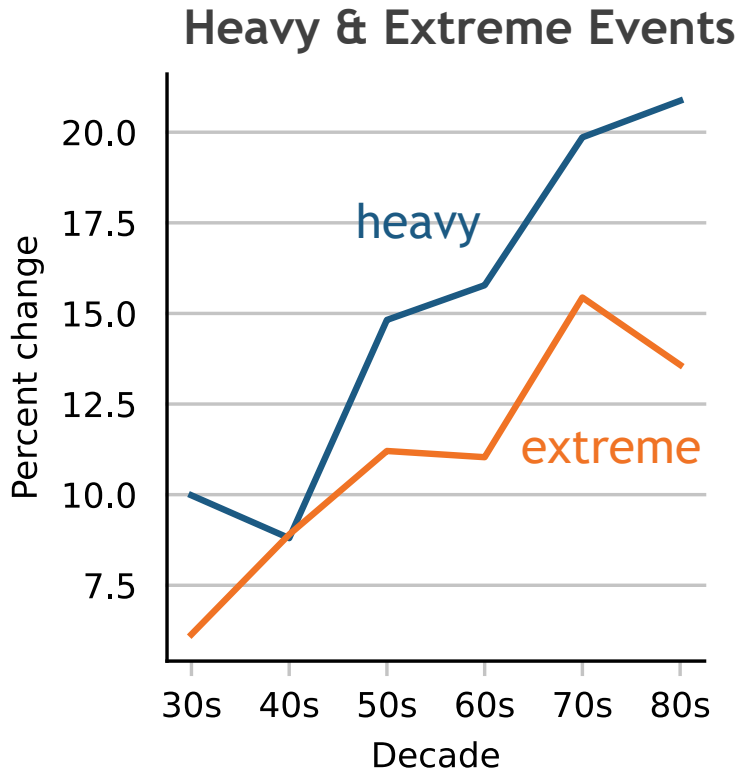
Extreme Events

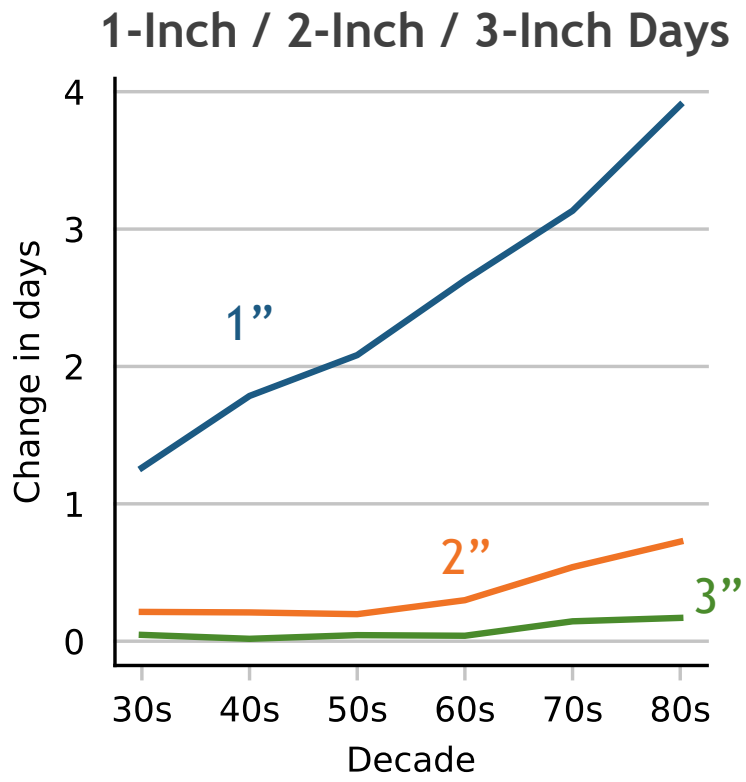
1-Inch Days

2 & 3-Inch Days

Late Summer



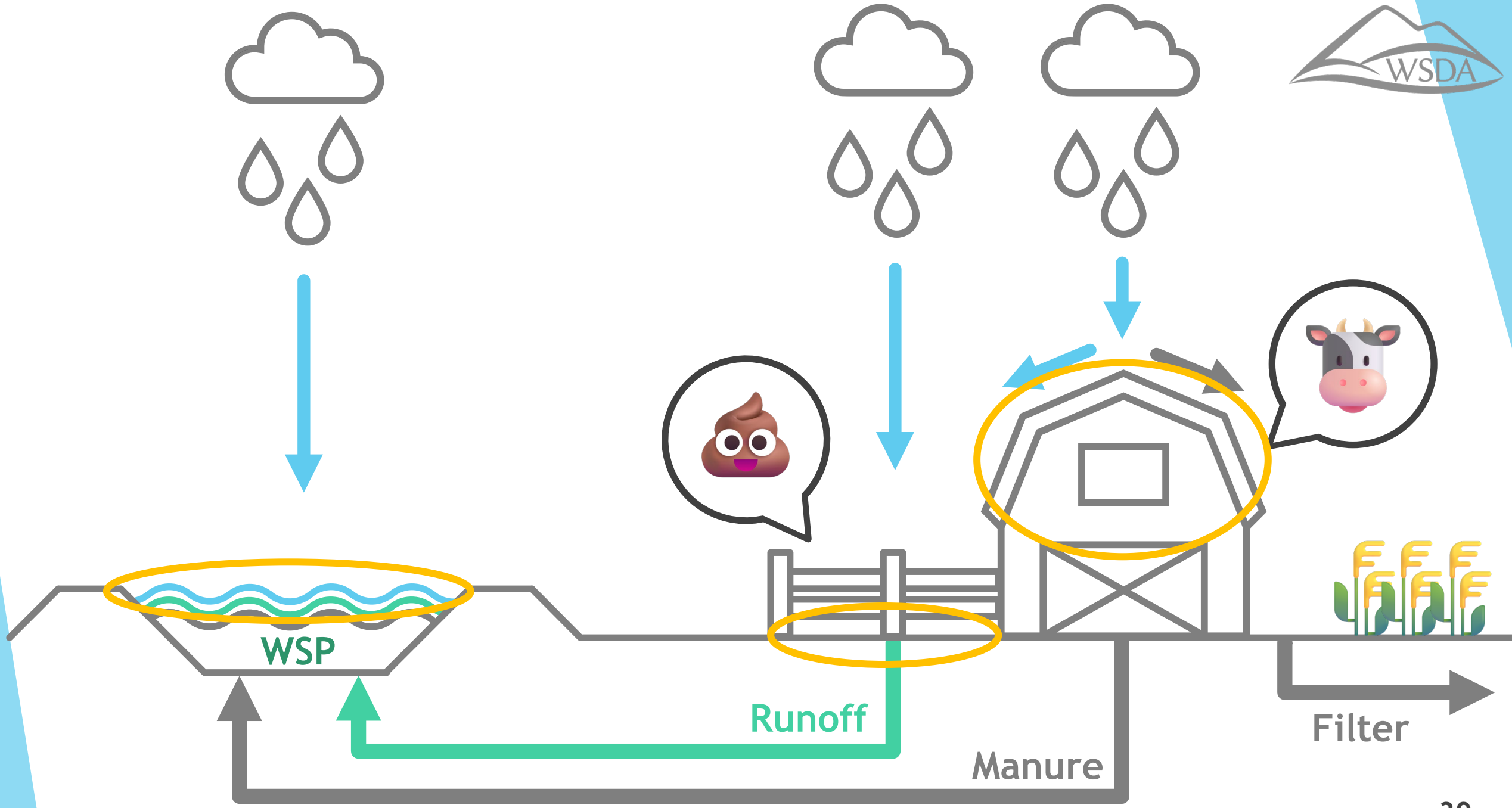




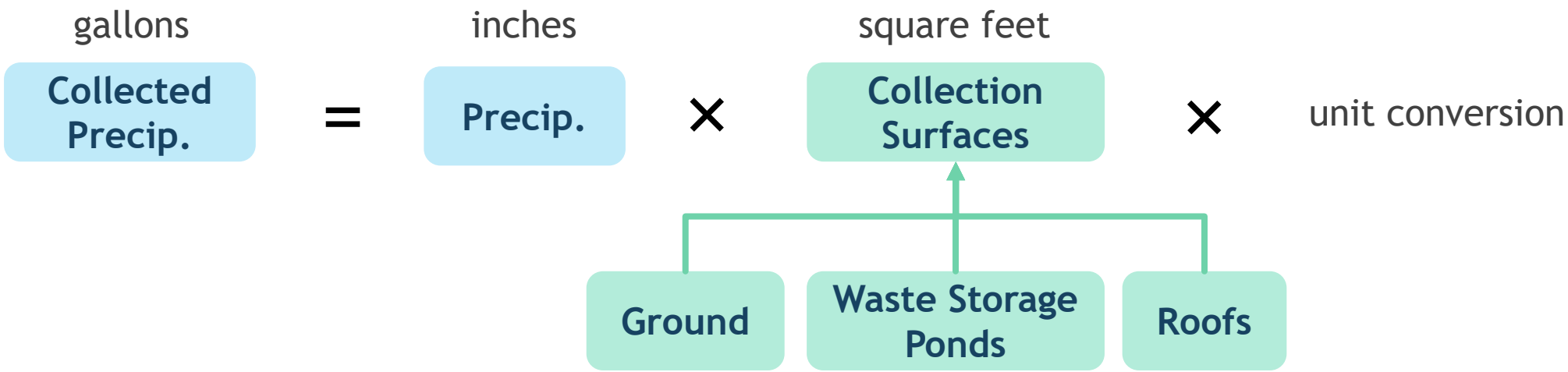
Raymond and Rogers. *Climate Mapping for a Resilient Washington.*

Processing the Data
GIS Features

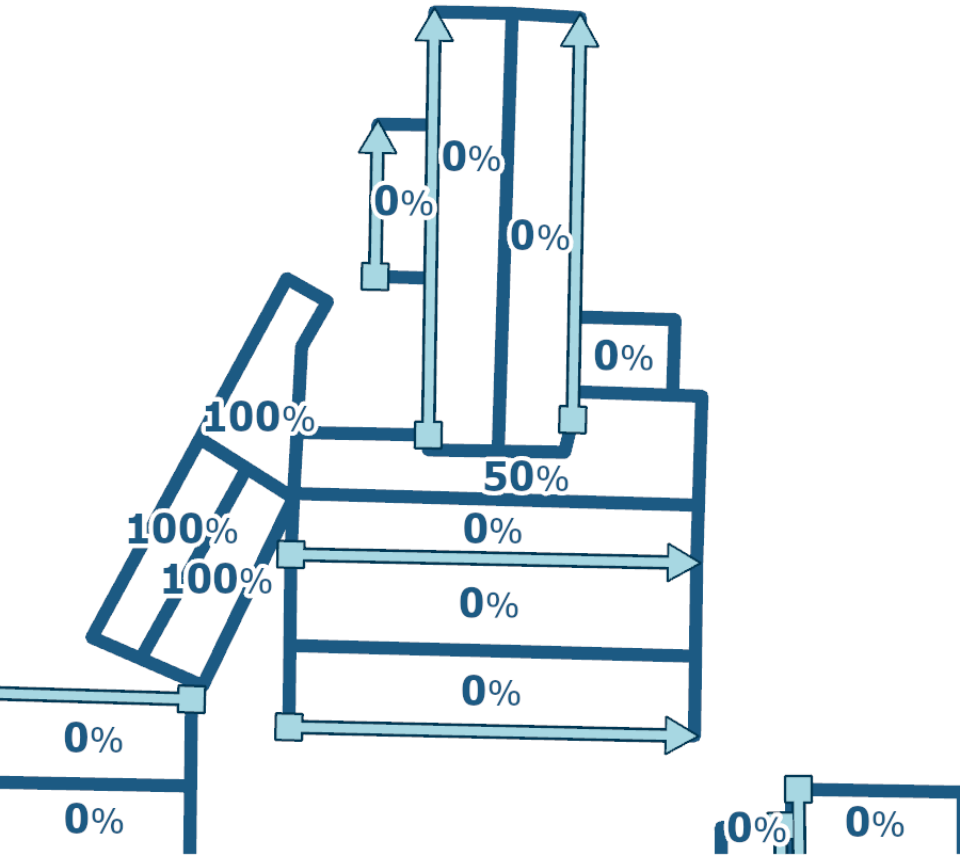
- Tasks
  - Total runoff area
  - Graphs
  - Generate maps


WSP
Runoff
Manure
Filter

Processing the Data
GIS Features



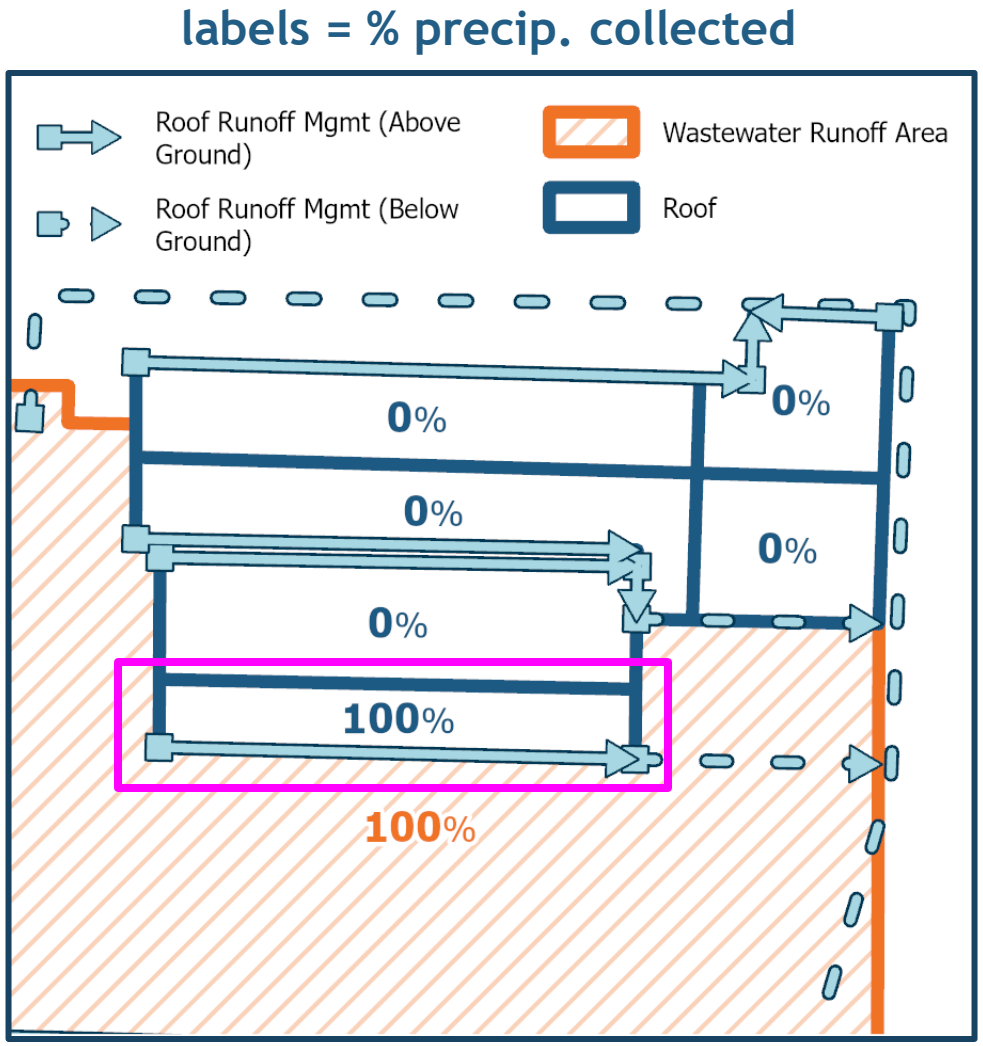
Processing the Data
GIS Features



- Estimating roof collection
  - Gutters?
    - Functional?
  - Where does the water go?
    - Waste storage ponds?
    - Vegetative buffer?
    - Crop field?
  - Above nutrient-contaminated ground?

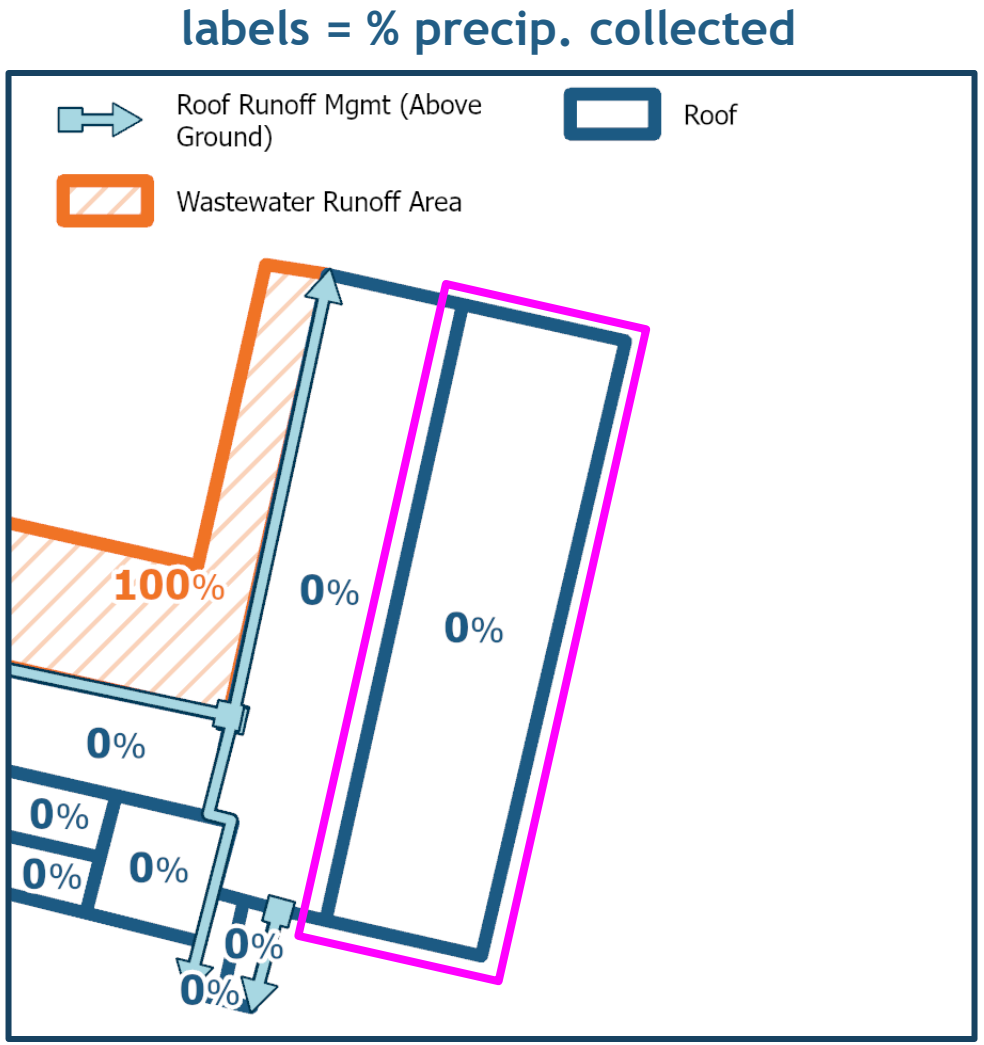
Processing the Data
GIS Features

- Example
  - Broken gutter
  - Collection area below



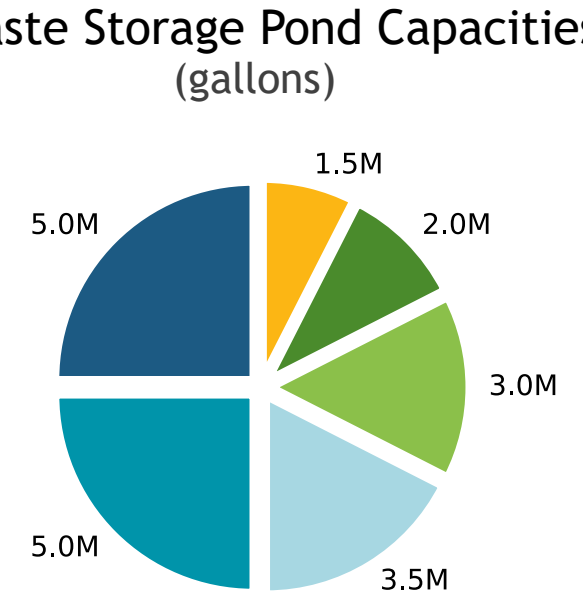
Processing the Data
GIS Features

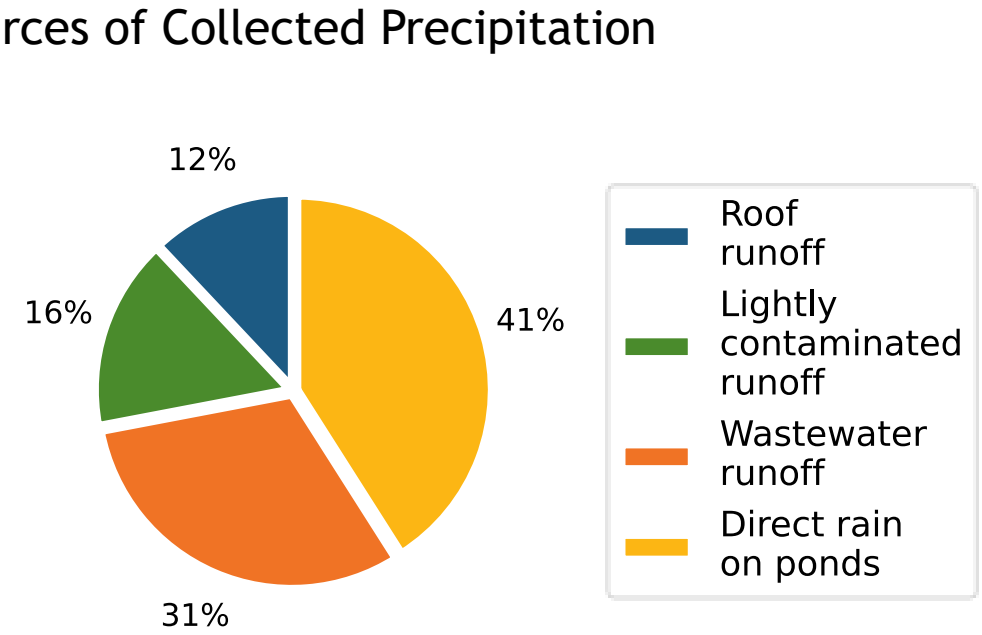
- Example
  - No gutters
  - No collection area below



Processing the Data
GIS Features

- Additional graphs (**matplotlib**)



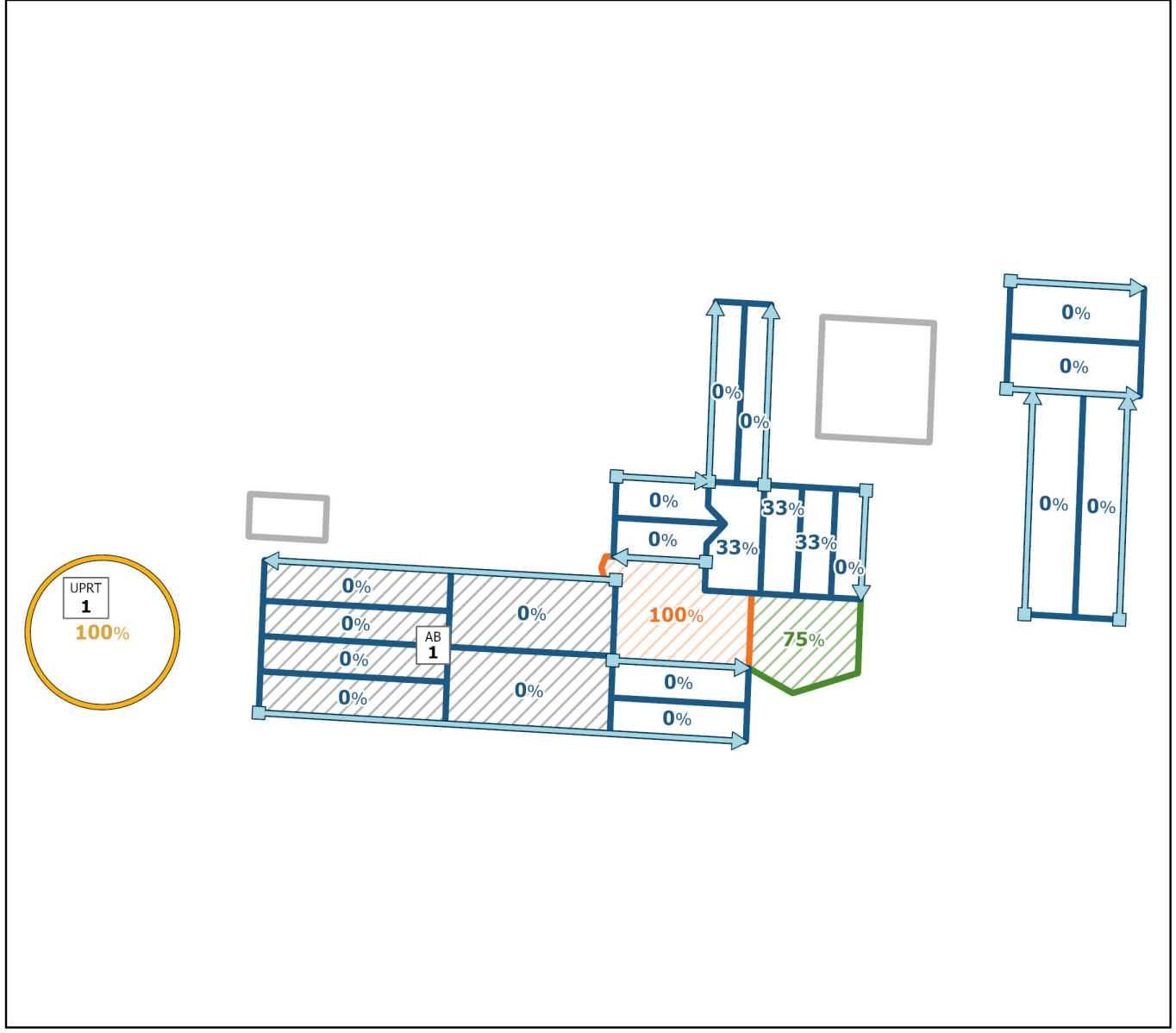


Processing the Data
GIS Features

- Rendering maps
  - ArcGIS Pro
  - Focused symbology

Processing the Data
GIS Features

- Rendering maps
  - ArcGIS Pro
  - Focused symbology

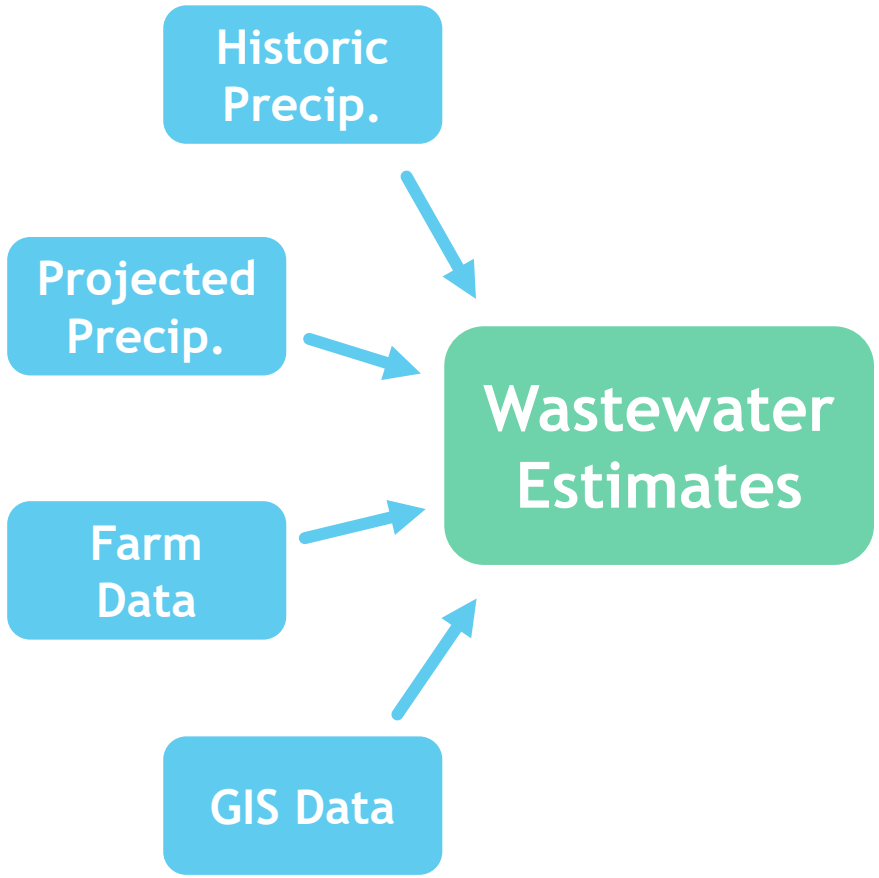


Processing the Data
GIS Features

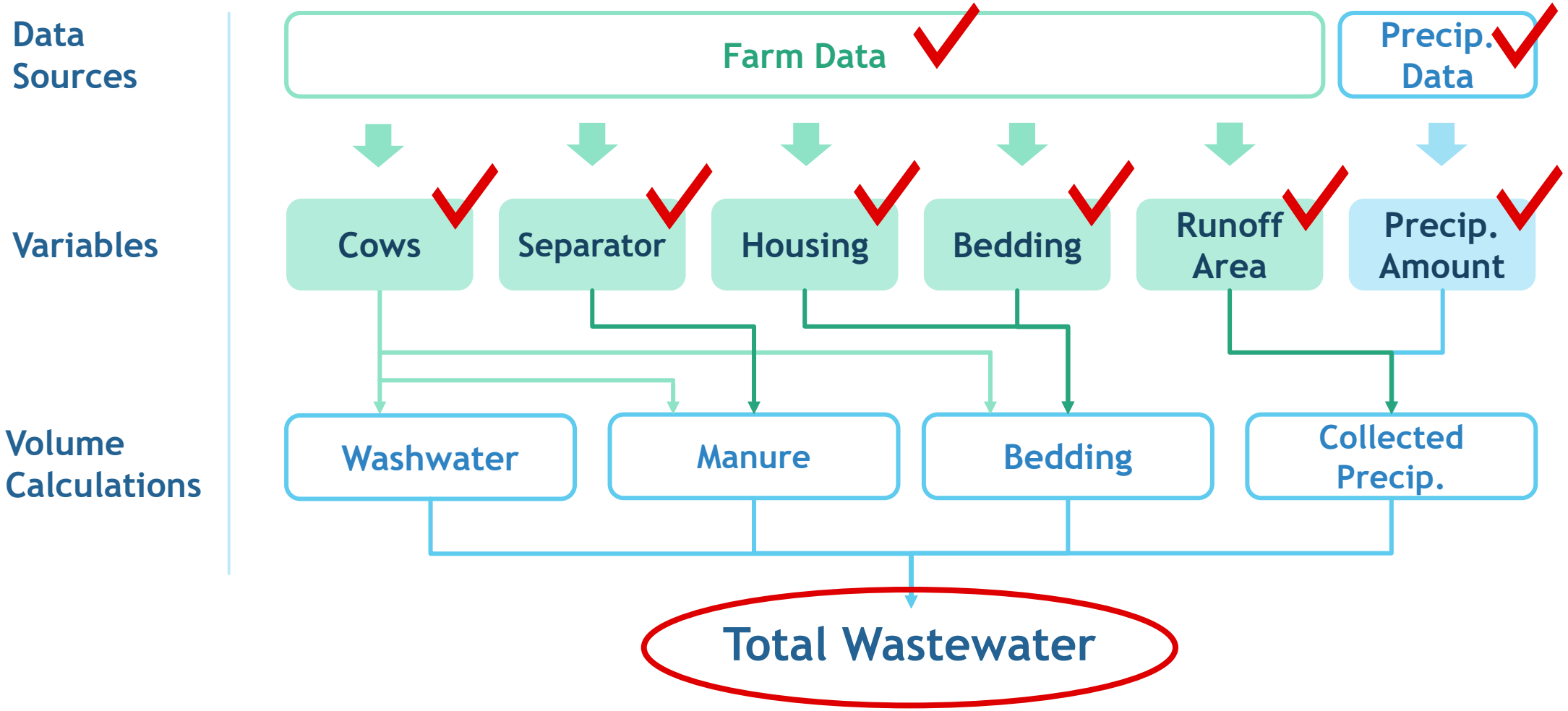
- Rendering maps
  - ArcGIS Pro
  - Focused symbology

Processing the Data
Combining Everything

- Tasks
  - Annual precip. collection
  - Wet season wastewater collection
  - Potential savings



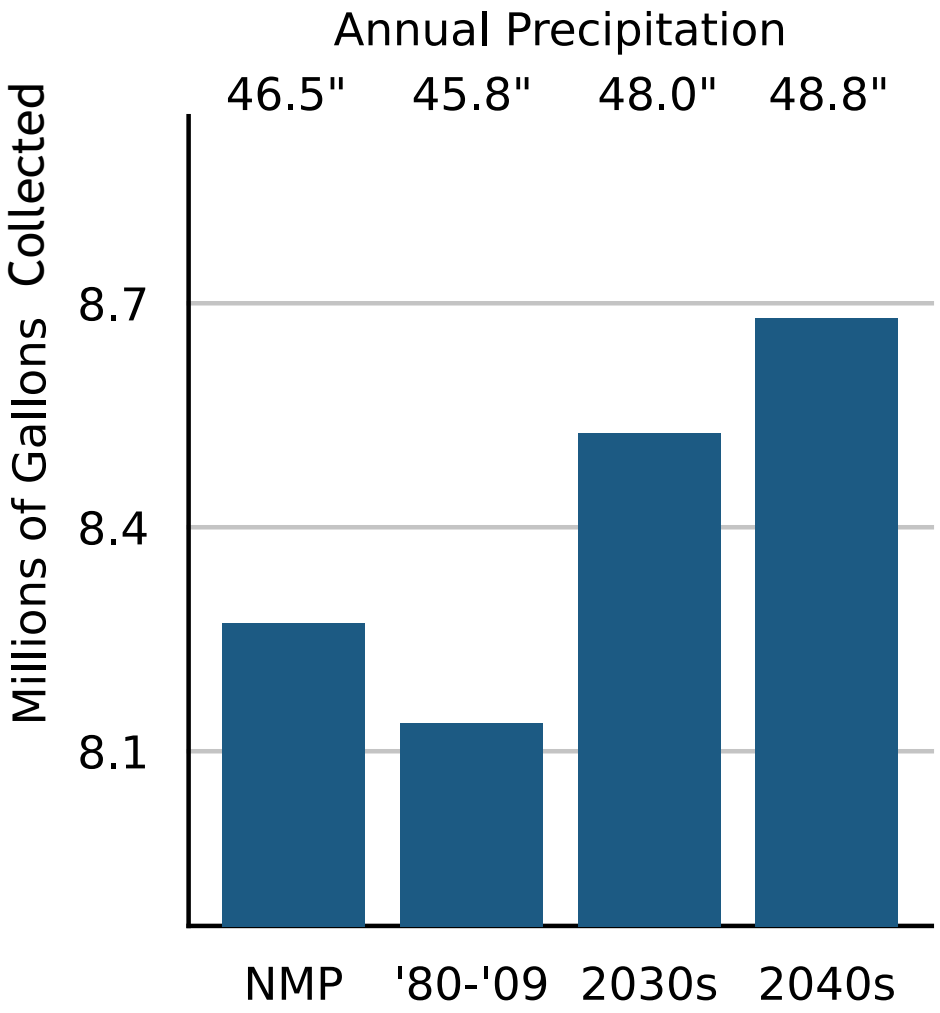
Background
Estimating Wastewater



Combining Everything
Projected Precip. + Surface Area

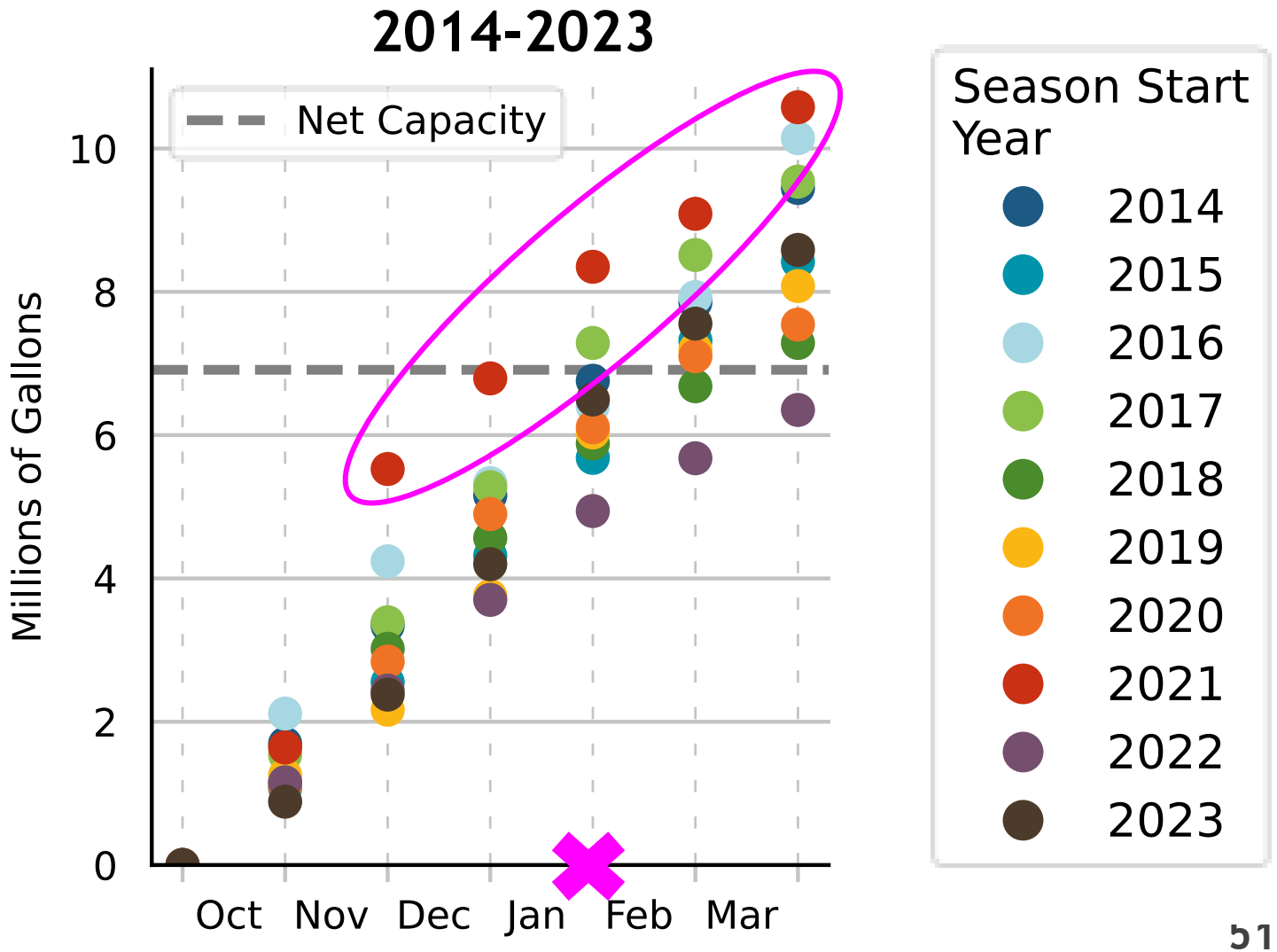
- Projected annual precipitation collection
  - **Matplotlib**

NMP = Nutrient Management Plan



Combining Everything
Historic Precip. + Farm Data

- Wet season cumulative wastewater collection
  - **matplotlib**
  - Visual tool
  - Estimate
  - *Not historic fact*
  - *Does not mean overtopping*
    - *Exports*
    - *Application windows*
  - 2021 emphasis
    - "What would you do differently?"

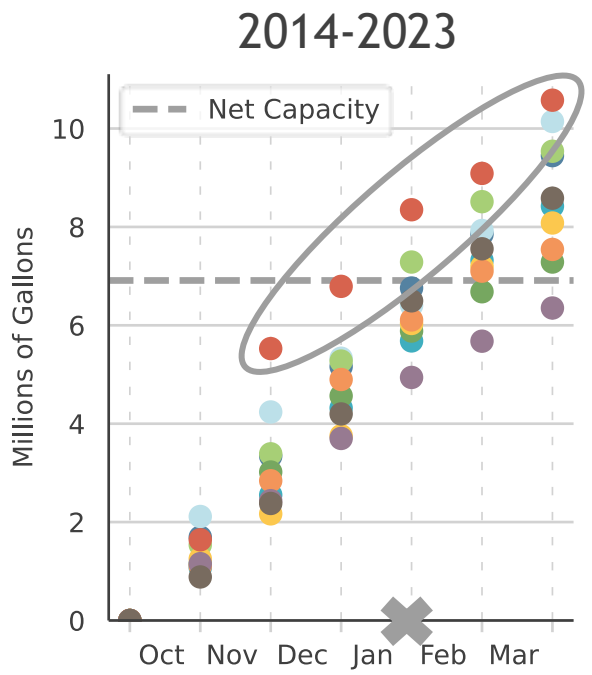


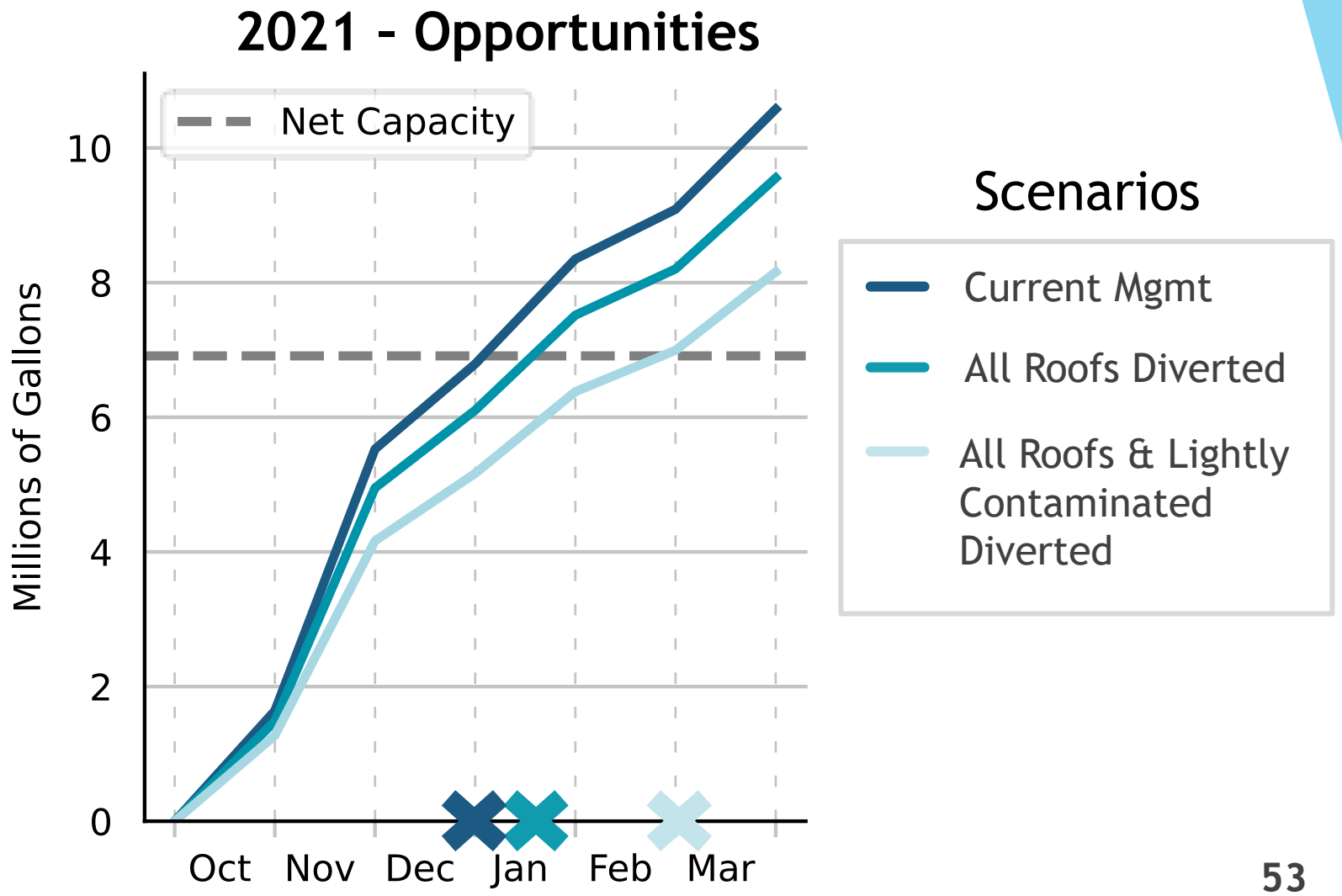
November 2021

Whatcom County

Combining Everything
Historic Precip. + Farm Data

- Wet season cumulative wastewater collection
  - **matplotlib**





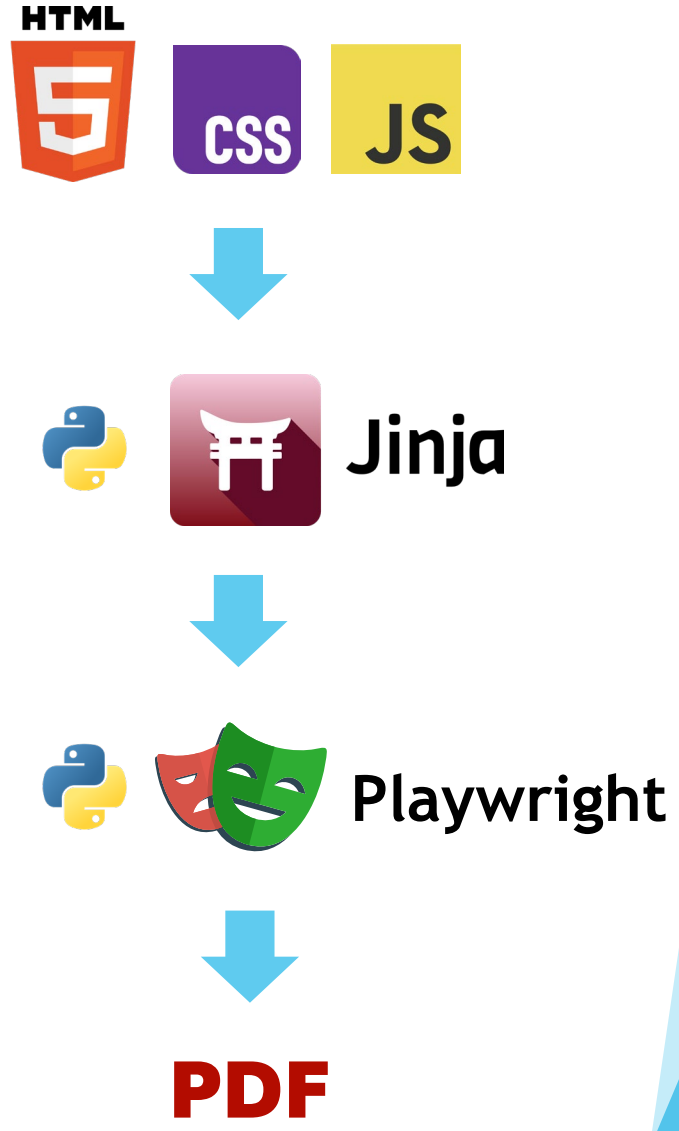
Report Design

Report Design
Deciding the Approach

- Expectations:
  - 50 dairies
  - Constant tweaks, changes
- Goal:
  - Automation
  - Uniformity
  - Quick changes
  - Avoid Microsoft Word
- Conclusion:
  - Template, populated using code

Report Design
HTML & Jinja

- **HTML / CSS / JS**
  - **HTML** to design template
  - **CSS** for easier styling
  - **JavaScript** to modify HTML when running
  - Include placeholder values
- **Jinja**
  - Replace placeholder values
- **Playwright**
  - print to PDF



Report Design
The Approach

- Why HTML?
  - Not MS Word
  - Prior experience
  - Flexible & precise
  - Can look great
- Other options exist

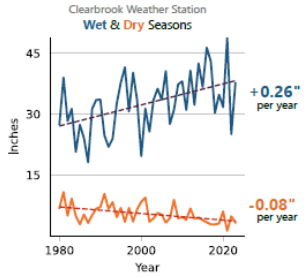
Report Design

Washington State Department of Agriculture
Nutrient Management Technical Services

Winter Storage Preparedness Estimate
Pilot Dairy

This **Winter Storage Preparedness Estimate** provides farm-specific insights based on your manure management system and local rainfall data. The estimate aims to help with planning, understanding storage needs, and identifying opportunities to improve manure and water management, thereby supporting on-farm resilience and water quality protection.

Historic Precipitation



Wet season rainfall has increased by an average of 0.26 inches per year since 1980. If this trend continues, it will add pressure on manure storage systems, increasing the risk of overtopping or applying under poor conditions if not managed proactively.

Dry season rainfall over this same period has decreased by an average of -0.08 inches per year, reducing water availability during the growing season. This makes stored liquid more valuable through the growing season.

Projected Precipitation
Change relative to 1980–2009

	Annual	Jul 15–Sep 15	25 Year Storm	>1" Days
2030s	+4.8% (48.0")	-2.6%	+7.1%	+0.8
2040s	+6.7% (48.8")	-14.1%	+17.7%	+0.9
	Total precipitation	Total precipitation	Magnitude	Days per year

Each number above is the median calculated from several models that generate a wide range of values.

Annual rainfall is projected to continue increasing over the next 5–15 years, with heavier and more frequent storm events.

Wet season rainfall will likely account for the majority of the increased annual precipitation.

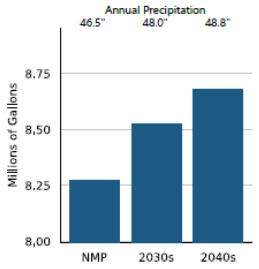
Late summer rainfall (June 15–September 15) is expected to decrease over the next 5–15 years.

Washington State Department of Agriculture
Nutrient Management Technical Services

Winter Storage Preparedness Estimate
Pilot Dairy

Estimated Rain Collection

- The chart to the right shows the estimated future **annual** rain collection using your current infrastructure.
- Roughly 177,800 gallons are collected for each inch of rain.



+181K gal / decade

Collection Area	285,200 ft²
Per Inch	177,800 gal
Per 10k ft²	317,300 gal

First column based on the precipitation average in your nutrient management plan.
Each precipitation average based on Clearbrook Weather Station.

Wet Season Rain Collection
Oct – Mar

6.4 M gallons from **36.3** inches

Potential Reductions

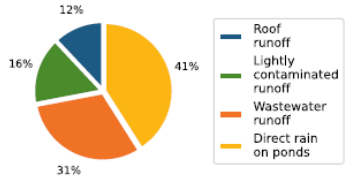
Lightly Contaminated Runoff — **1.04 M** fewer gallons
By diverting water on the ground

Roof Runoff — **0.76 M** fewer gallons
By installing additional gutters and/or repairing existing ones

Largest Pond — **1.1 M** fewer gallons
By covering the pond and diverting rainwater

Based on average precipitation from 2004–2023 Clearbrook Weather Station

Collected Water Composition



Of the rainwater collected on your farm:
- 41% falls directly into waste storage structures
- 31% is wastewater runoff
- 16% is lightly contaminated runoff
- 12% is roof runoff

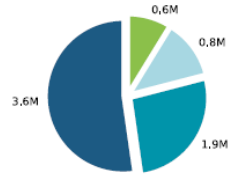
Definitions
Collected: liquid is contained, collected and transferred to storage.
Diverted: liquid is diverted away from collection and storage
Roof runoff: clean runoff from roofs that are uncontaminated by direct animal manure, feed, or process activities.
Lightly contaminated runoff: driveway, concrete slab, or other lightly contaminated water not allowed for direct discharge.
Wastewater runoff: production area water that mixes with manure and must be contained and stored for land application.

Washington State Department of Agriculture
Nutrient Management Technical Services

Winter Storage Preparedness Estimate
Pilot Dairy

Estimated Combined Wastewater Collection

Waste Storage Structures
Net Capacities (Gallons)

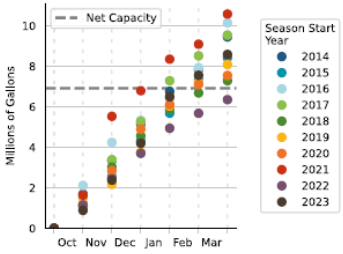


Total **6.91 M**

What goes into the collection calculation?
- cow numbers
- cow weight
- cow breed
- bedding material
- separator efficiency
- freestall or pen
- flush or scrape
- inches of rain

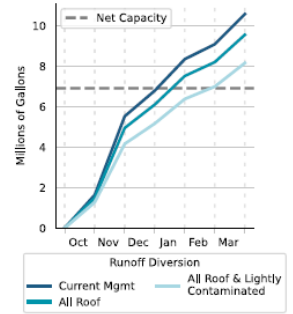
Combined wastewater components
manure + bedding + washwater + rain

Wet Season Cumulative Collection
Past 10 Years



This graph shows an estimate of how much manure and wastewater was collected over the course of the storage season for the past 10 years using historic precipitation data and your current infrastructure and herd size. The horizontal line marks the total net storage capacity.

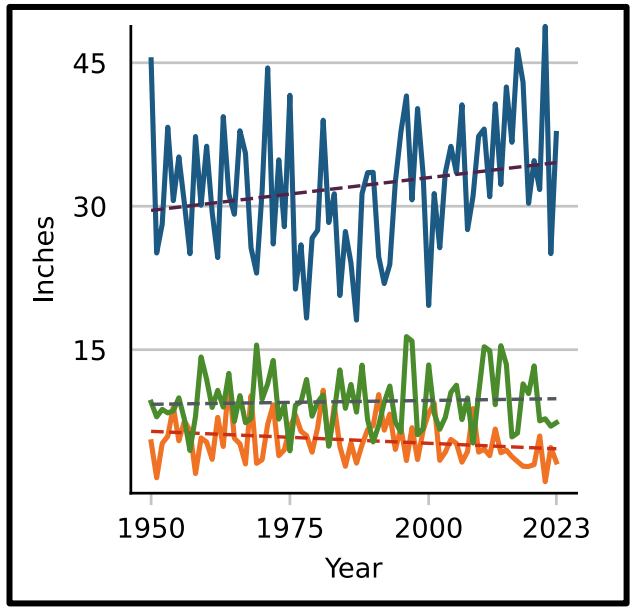
2021 Wet Season Cumulative Collection
Runoff Mgmt. Scenarios



This graph shows potential management scenarios for diverting roof and ground areas. These scenarios are calculated using precipitation data from the 2021-2022 storage season, the wettest season in recent years, with conditions similar to those expected in the future.

Report Design

- WSDA color palette




```python
def get_WSDA_palette():
    palette = [
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        "#0094AA",
        "#A7D7E2",
        "#8BC04A",
        "#4A8B2C",
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        "#F07325",
        "#CA3014",
        "#754F6D",
        "#4C3B2B",
    ]
    return palette
```
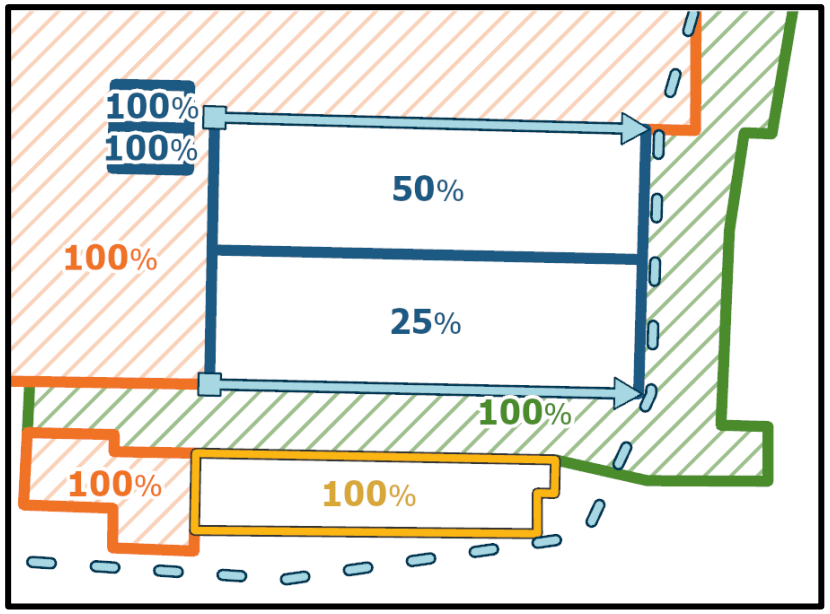
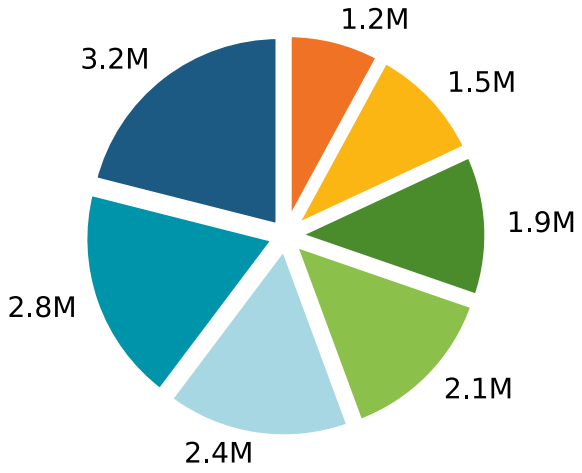



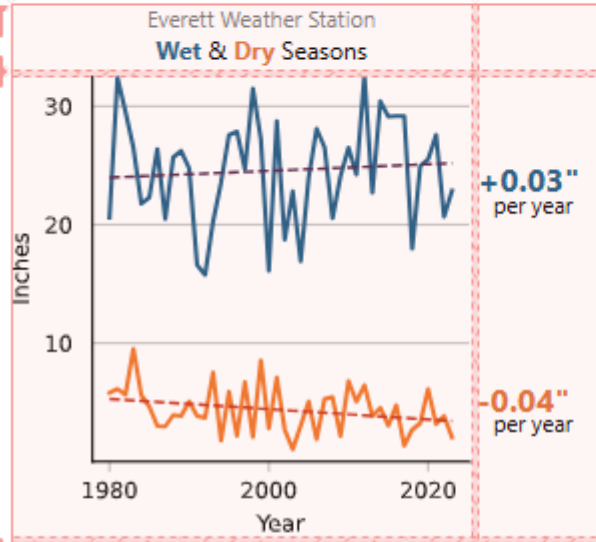


Report Design

HTML Grid display

This **Winter Storage Preparedness Estimate** provides farm-specific insights based on your manure management system and local rainfall data. The estimate aims to help with planning, understanding storage needs, and identifying opportunities to improve manure and water management, thereby supporting on-farm resilience and water quality protection.

Historic Precipitation



Wet season rainfall has increased by an average of 0.03 inches per year since 1980. If this trend continues, it will add pressure on manure storage systems, increasing the risk of overtopping or applying under poor conditions if not managed proactively.

Dry season rainfall over this same period has decreased by an average of -0.04 inches per year, reducing water availability during the growing season. This makes stored liquid more valuable through the growing season.

Projected Precipitation

Change relative to 0–2009

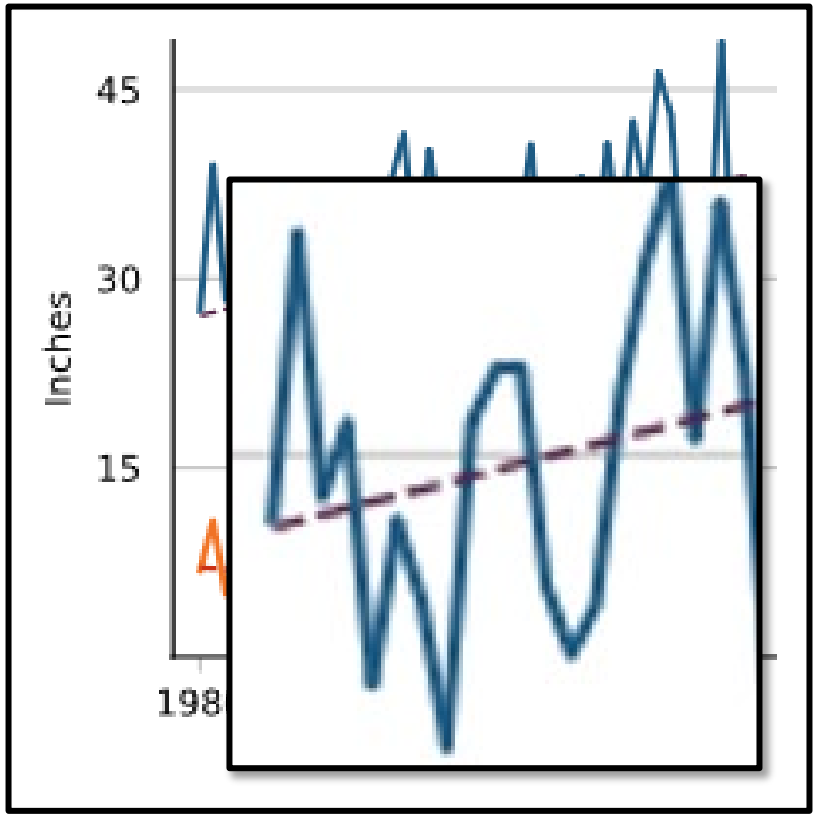
	Annual	Jul 15–Sep 15	25 Year Storm	>1" Days
2030s	+6.9% 38.1"	-4.3%	+3.9%	+1.1
2040s	+8.6% 38.7"	-6.5%	+1.5%	+1.5
	Total precipitation	Total precipitation	Magnitude	Days per year

Each number above is the median calculated from several models that generate a wide range of values.

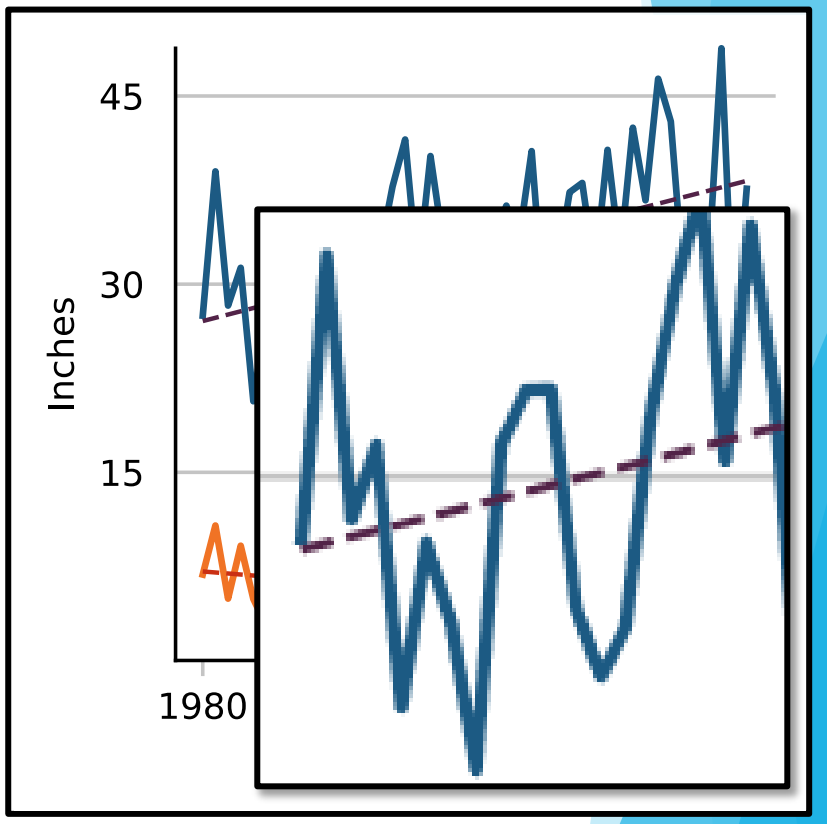
Report Design

- **matplotlib savefig()**
  - SVG > PNG
  - PNGs printed blurry

PNG



SVG

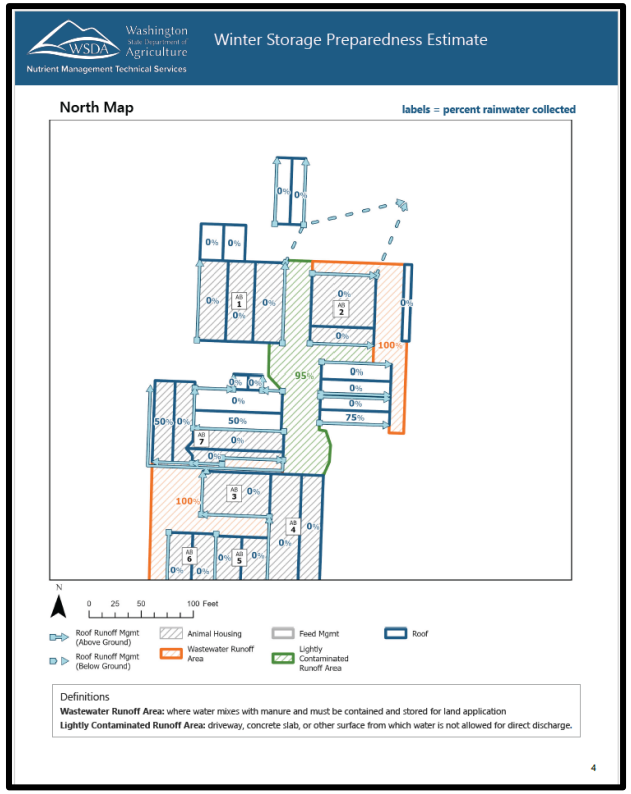


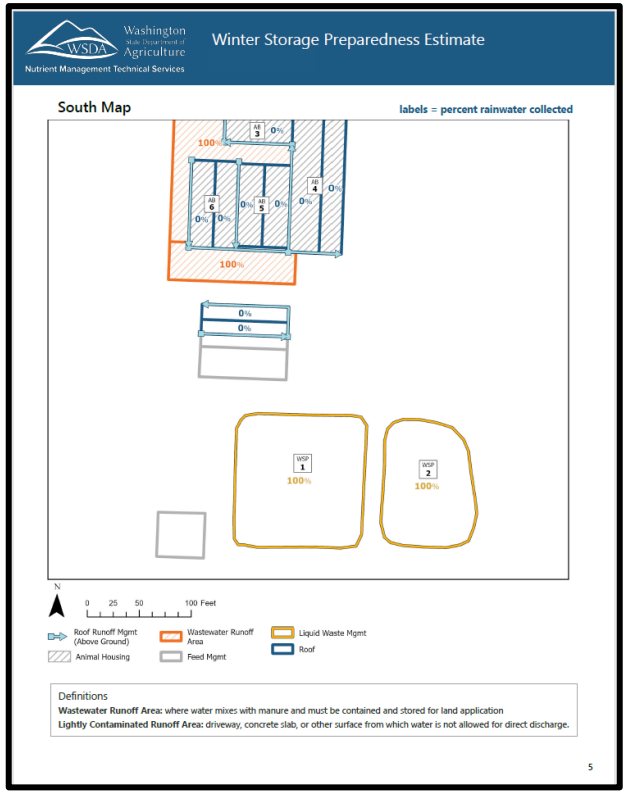
Report Design

- JavaScript: modify the HTML
  - Add map pages (varying amount)
  - Add headers to each page
  - Create tables (unique for each dairy)

Washington State Department of Agriculture
Nutrient Management Technical Services

Winter Storage Preparedness Estimate
Pilot Dairy



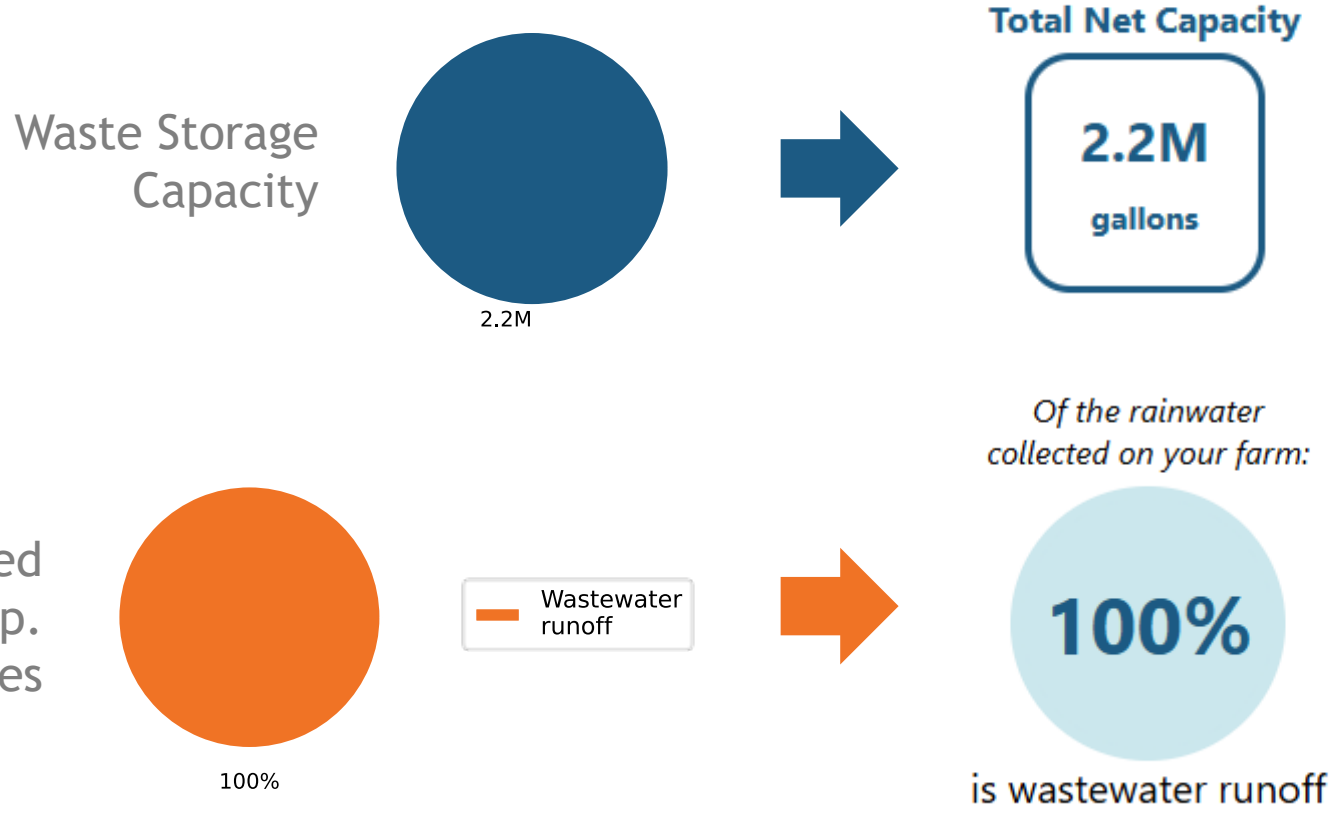


Dairy

Type	Square Feet	Percent Collected	Wet Season Gal.
Wastewater Area	58,510	100%	1,322,000
Wastewater Area	3,180	100%	72,000
Lightly Cont. Area	3,870	100%	87,000
Lightly Cont. Area	27,150	100%	614,000
Lightly Cont. Area	5,730	100%	129,000
Roof (AB 2)	2,100	100%	48,000
Roof	690	100%	16,000
Roof	710	100%	16,000
Roof (AB 1)	12,510	50%	141,000

Report Design

- JavaScript: modify the HTML
  - Replace “circle” charts



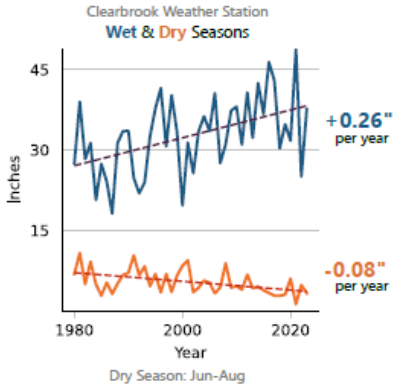
Report
Page 1

Washington State Department of Agriculture
Nutrient Management Technical Services

Winter Storage Preparedness Estimate
Pilot Dairy

This **Winter Storage Preparedness Estimate** provides farm-specific insights based on your manure management system and local rainfall data. The estimate aims to help with planning, understanding storage needs, and identifying opportunities to improve manure and water management, thereby supporting on-farm resilience and water quality protection.

Historic Precipitation



Wet season rainfall has increased by an average of 0.26 inches per year since 1980. If this trend continues, it will add pressure on manure storage systems, increasing the risk of overtopping or applying under poor conditions if not managed proactively.

Dry season rainfall over this same period has decreased by an average of -0.08 inches per year, reducing water availability during the growing season. This makes stored liquid more valuable through the growing season.

Projected Precipitation

Change relative to 1980–2009

	Annual	Jul 15–Sep 15	25 Year Storm	>1" Days
2030s	+4.8% (48.0")	-2.6%	+7.1%	+0.8
2040s	+6.7% (48.8")	-14.1%	+17.7%	+0.9
	Total precipitation	Total precipitation	Magnitude	Days per year

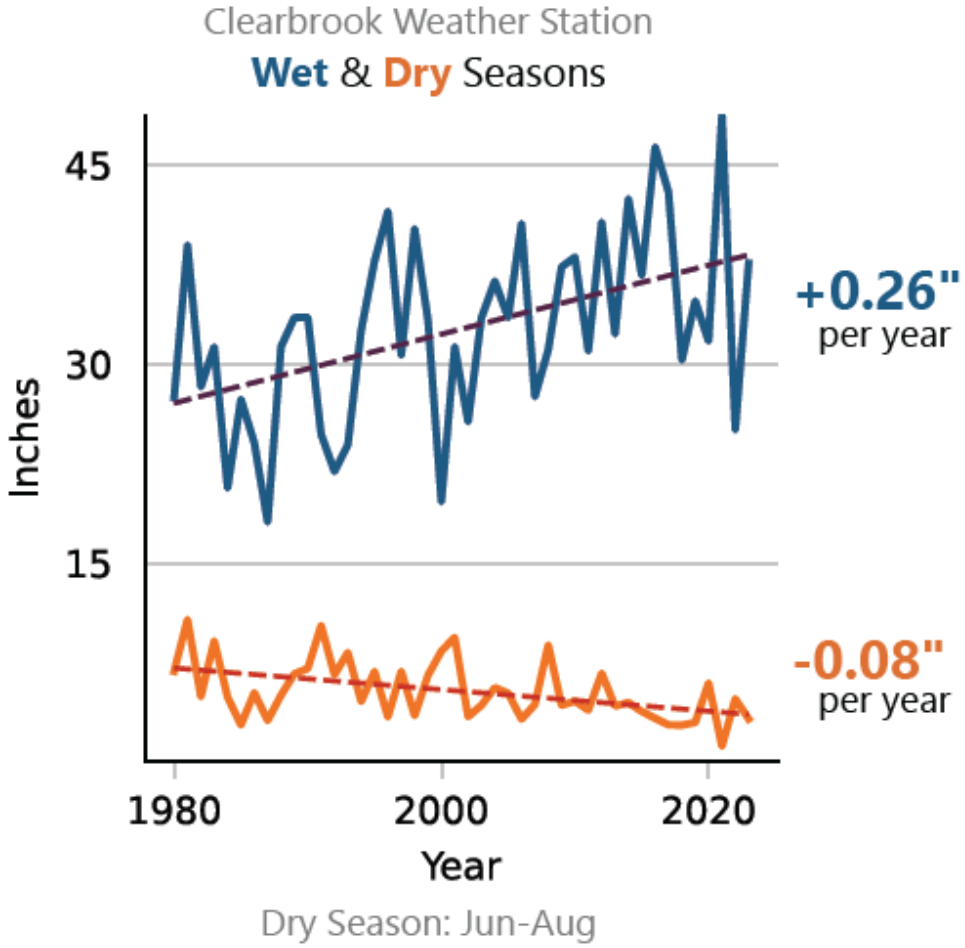
Each number above is the median calculated from several models that generate a wide range of values.

Annual rainfall is projected to continue increasing over the next 5–15 years, with heavier and more frequent storm events.

Wet season rainfall will likely account for the majority of the increased annual precipitation.

Late summer rainfall (June 15–September 15) is expected to decrease over the next 5–15 years.

Historic Precipitation



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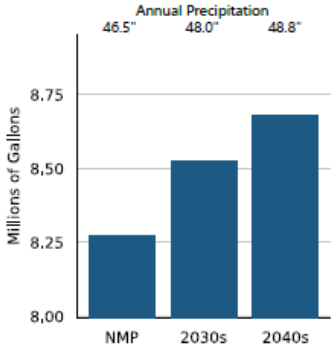
Report
Page 2

Washington State Department of Agriculture
Nutrient Management Technical Services

Winter Storage Preparedness Estimate
Pilot Dairy

Estimated Rain Collection

- The chart to the right shows the estimated future **annual** rain collection using your current infrastructure.
- Roughly 177,800 gallons are collected for each inch of rain.



+181K gal / decade

Collection Area	285,200 ft²
Per Inch	177,800 gal
Per 10k ft²	317,300 gal

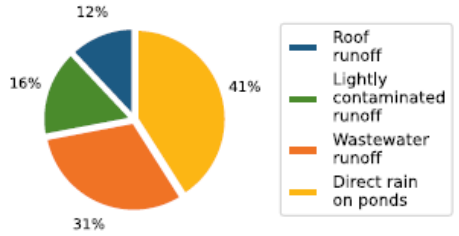
First column based on the precipitation average in your nutrient management plan.
Each precipitation average based on Clearbrook Weather Station.

Wet Season Rain Collection

Oct – Mar

6.4 M gallons from **36.3** inches

Collected Water Composition



Potential Reductions

Lightly Contaminated Runoff
1.04 M fewer gallons
By diverting water on the ground

Roof Runoff
0.76 M fewer gallons
By installing additional gutters and/or repairing existing ones

Largest Pond
1.1 M fewer gallons
By covering the pond and diverting rainwater

Based on average precipitation from 2004–2023
Clearbrook Weather Station

Of the rainwater collected on your farm:

- 41% falls directly into waste storage structures
- 31% is wastewater runoff
- 16% is lightly contaminated runoff
- 12% is roof runoff

Definitions

Collected: liquid is contained, collected and transferred to storage.
Diverted: liquid is diverted away from collection and storage
Roof runoff: clean runoff from roofs that are uncontaminated by direct animal manure, feed, or process activities.
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2

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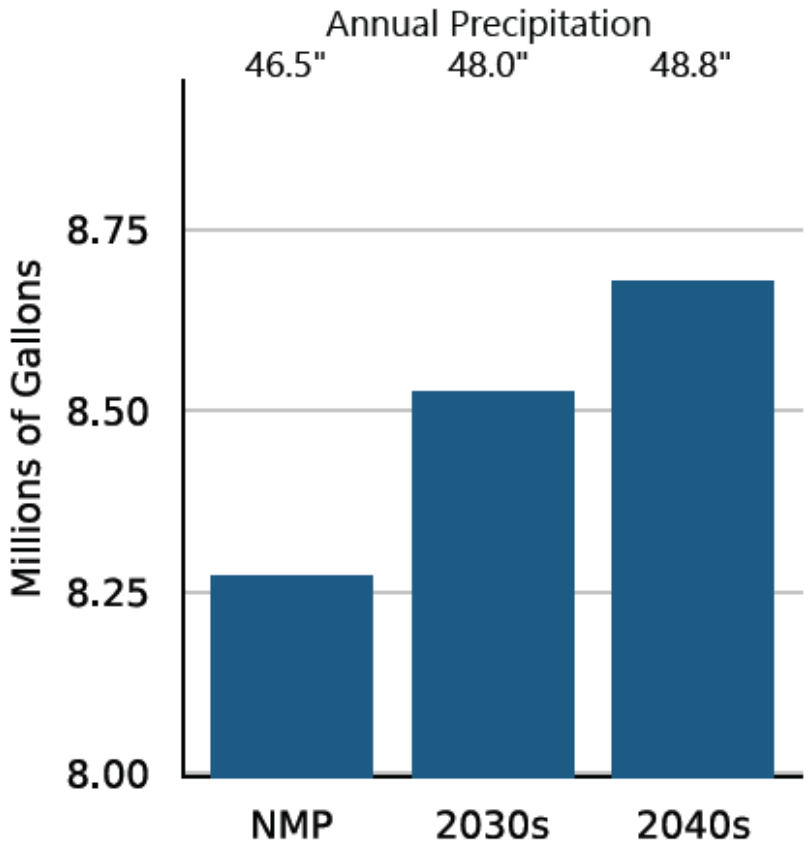

+181K
gal / decade

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Per 10k ft^2	317,300 gal

First column based on the precipitation average in your nutrient management plan.
Each precipitation average based on Clearbrook Weather Station.

Wet Season Rain Collection

Oct – Mar

6.4 M gallons **from** **36.3** inches

Potential Reductions

Lightly Contaminated Runoff

1.04 M fewer gallons

By diverting water on the ground (through veg. buffer)

Roof Runoff

0.76 M fewer gallons

By installing additional gutters and/or repairing existing ones

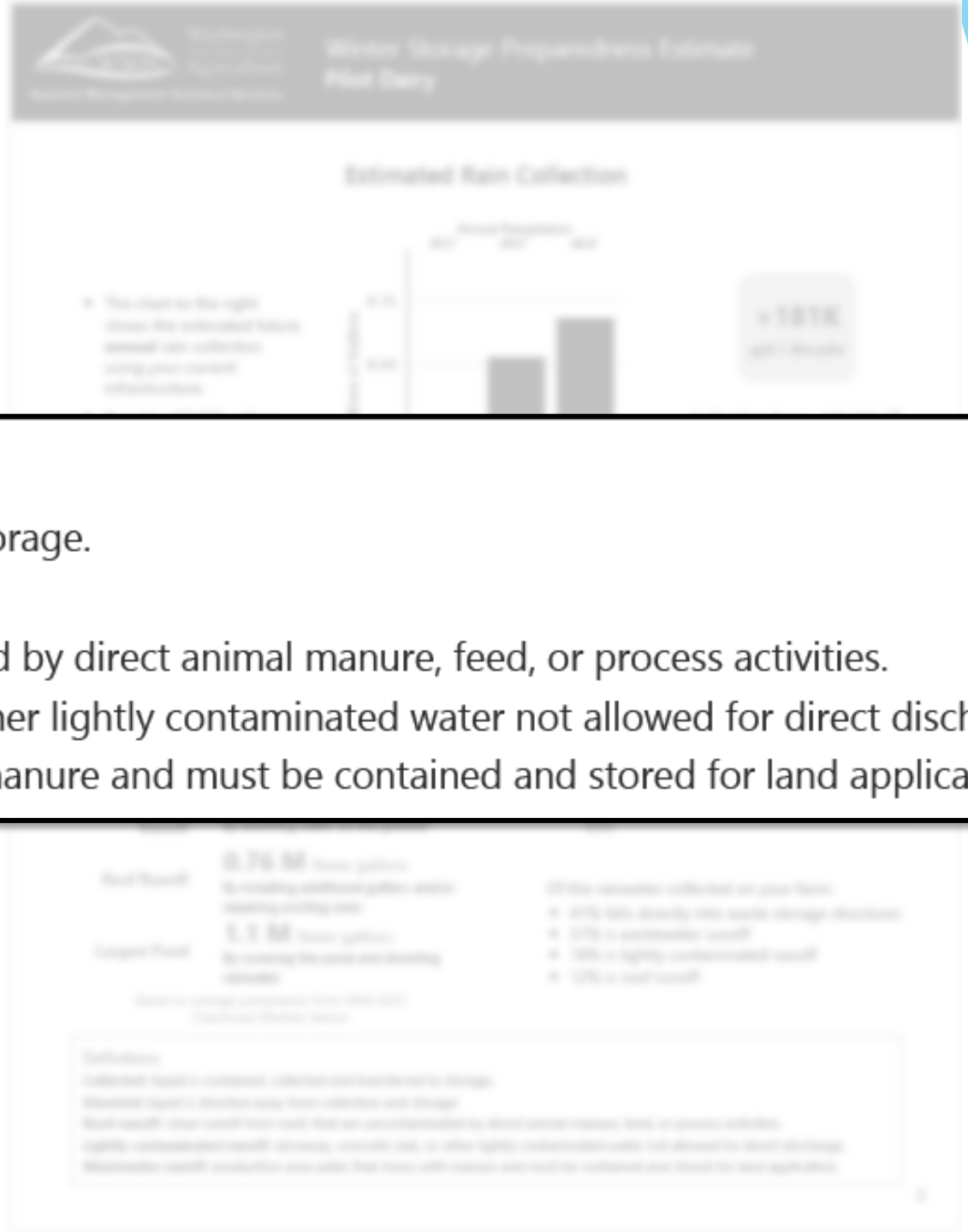
Largest Pond

1.1 M fewer gallons

By covering the pond and diverting rainwater

Based on average precipitation from 2004–2023
Clearbrook Weather Station

WSDA



Definitions

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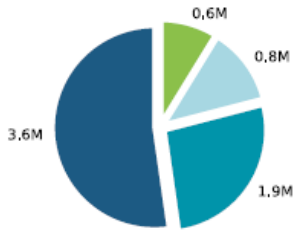
Report
Page 3

Washington State Department of Agriculture
Nutrient Management Technical Services

Winter Storage Preparedness Estimate
Pilot Dairy

Estimated Combined Wastewater Collection

Waste Storage Structures
Net Capacities (Gallons)



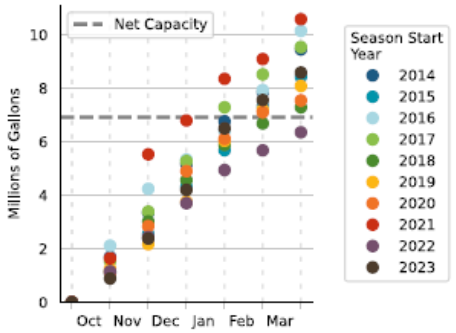
Total **6.91 M**

What goes into the collection calculation?

- cow numbers
- cow weight
- cow breed
- bedding material
- separator efficiency
- freestall or pen
- flush or scrape
- inches of rain

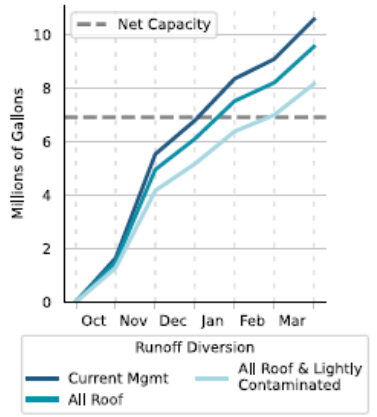
Combined wastewater components
manure + bedding + washwater + rain

Wet Season Cumulative Collection
Past 10 Years



This graph shows an estimate of how much manure and wastewater was collected over the course of the storage season for the past 10 years using historic precipitation data and your current infrastructure and herd size. The horizontal line marks the total net storage capacity.

2021 Wet Season Cumulative Collection
Runoff Mgmt. Scenarios



This graph shows potential management scenarios for diverting roof and ground areas. These scenarios are calculated using precipitation data from the 2021-2022 storage season, the wettest season in recent years, with conditions similar to those expected in the future.

What goes into the collection calculation?

- cow numbers
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- cow breed
- bedding material
- separator efficiency
- freestall or pen
- flush or scrape
- inches of rain

Combined wastewater components

manure + bedding + washwater + rain

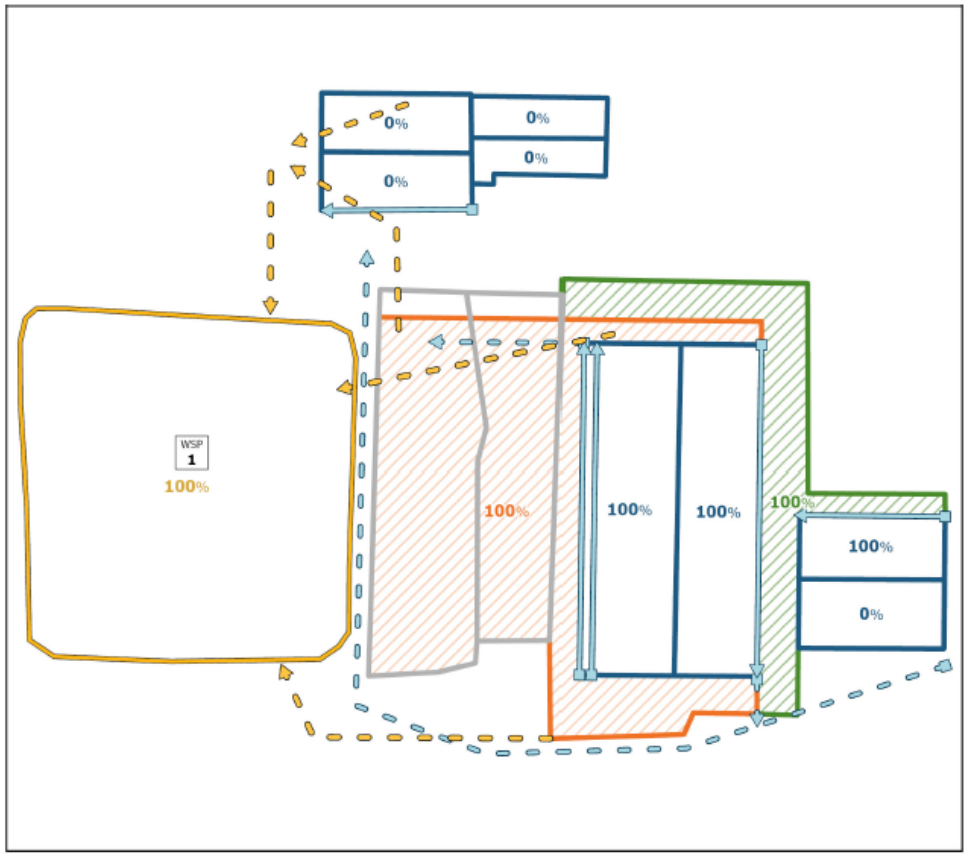
Report
Map(s)

Washington State Department of Agriculture
Nutrient Management Technical Services

Winter Storage Preparedness Estimate
Pilot Dairy

Dry Cow Map

labels = percent rainwater collected



N

0 25 50 100 Feet

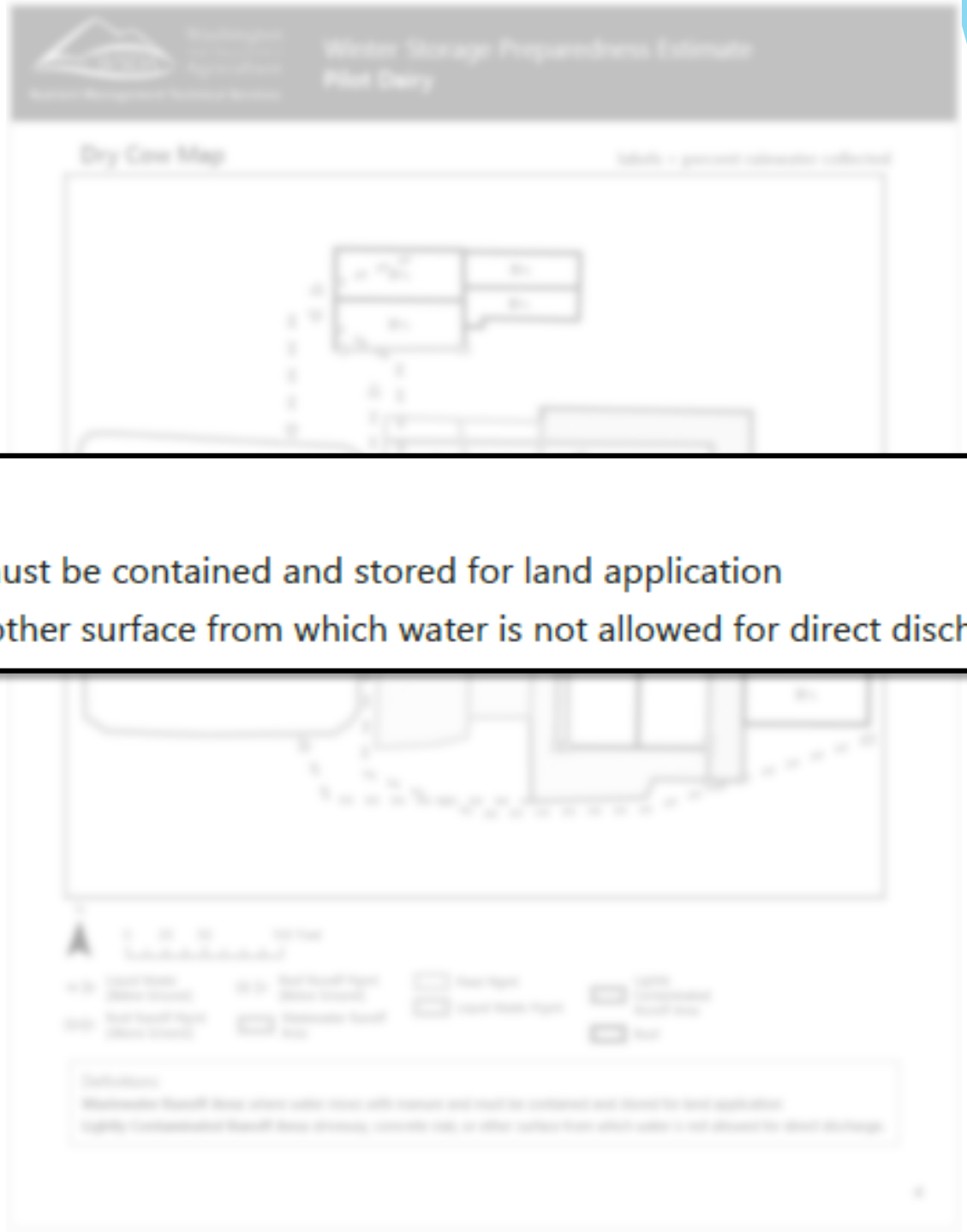
Liquid Waste (Below Ground)
Roof Runoff Mgmt (Above Ground)
Roof Runoff Mgmt (Below Ground)
Wastewater Runoff Area
Feed Mgmt
Liquid Waste Mgmt
Lightly Contaminated Runoff Area
Roof

Definitions

Wastewater Runoff Area: where water mixes with manure and must be contained and stored for land application

Lightly Contaminated Runoff Area: driveway, concrete slab, or other surface from which water is not allowed for direct discharge.

4



Definitions

Wastewater Runoff Area: where water mixes with manure and must be contained and stored for land application

Lightly Contaminated Runoff Area: driveway, concrete slab, or other surface from which water is not allowed for direct discharge.

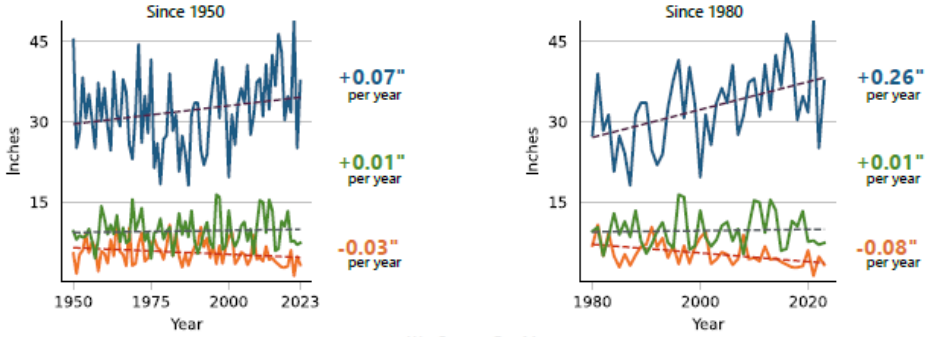
Report
Additional Precip. Details

Washington State Department of Agriculture
Nutrient Management Technical Services

Winter Storage Preparedness Estimate
Pilot Dairy

Historic Precipitation
Clearbrook Weather Station

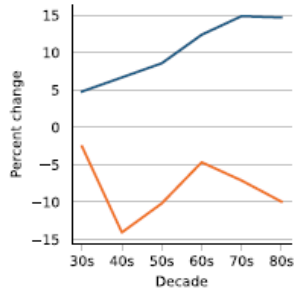
Wet, **Dry** & **Shoulder** Seasons



Wet Season: Oct–Mar
Dry Season: Jun–Aug
Shoulder Season: Sep, Apr & May

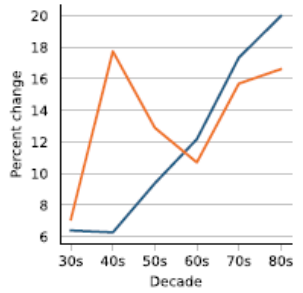
Projected Precipitation
2030–2080
Change relative to 1980–2009

Annual & **Late Summer**



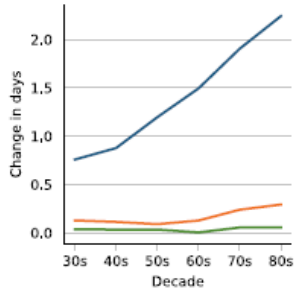
Late Summer: Jul 15–Sep 15

Heavy & **Extreme** Event Magnitude



Heavy: 24-hour / 2-year
Extreme: 24-hour / 25-year

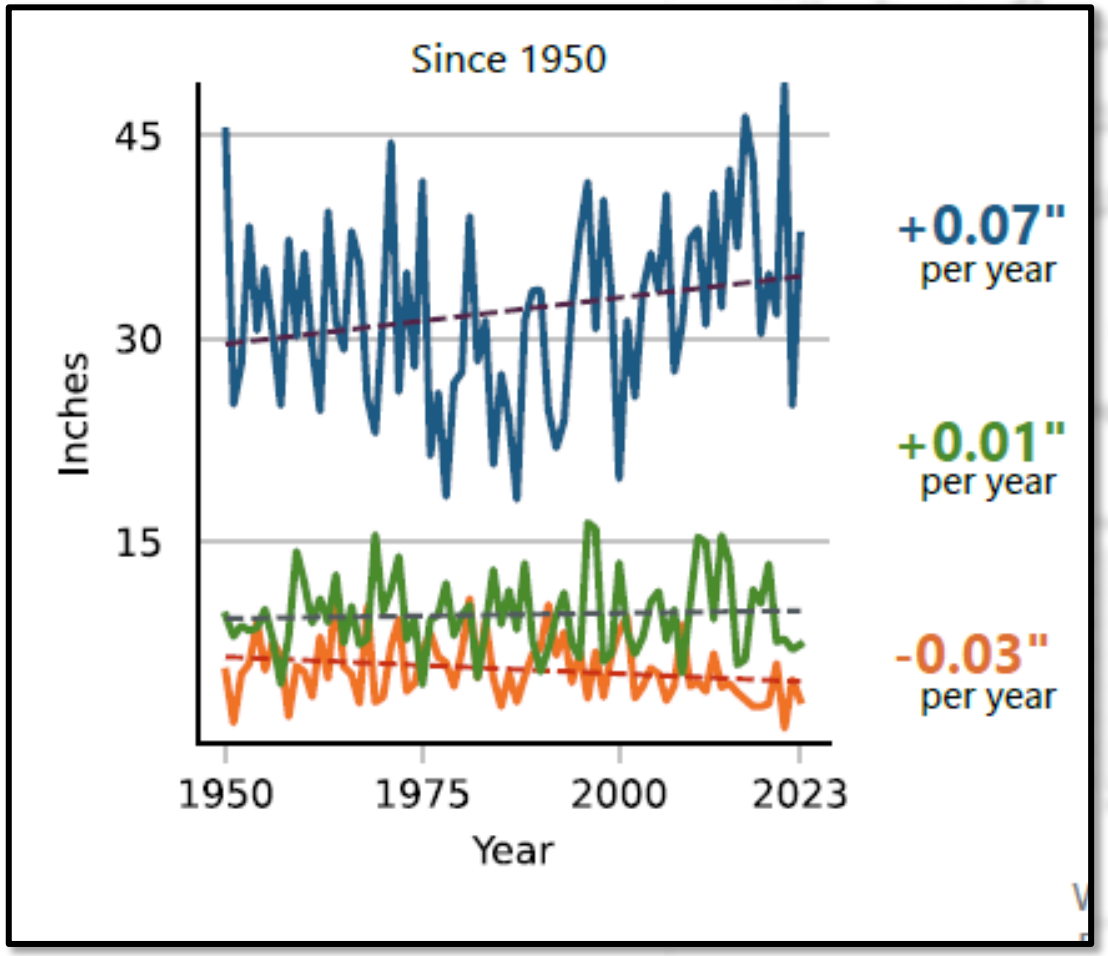
1-Inch, **2-Inch** & **3-Inch** Days



The numbers depicted in the charts above are medians calculated from several models that generate a wide range of values.

7

Report Design



Report
Infrastructure Details

Washington State Department of Agriculture
Nutrient Management Technical Services

Winter Storage Preparedness Estimate
Pilot Dairy

Infrastructure: Precipitation Collection

Dairy

Type	Square Feet	Percent Collected	Wet Season Gal.
Wastewater Area	58,510	100%	1,322,000
Wastewater Area	3,180	100%	72,000
Lightly Cont. Area	3,870	100%	87,000
Lightly Cont. Area	27,150	100%	614,000
Lightly Cont. Area	5,730	100%	129,000
Roof (AB 2)	2,100	100%	48,000
Roof	690	100%	16,000
Roof	710	100%	16,000
Roof (AB 1)	12,510	50%	141,000
Roof (AB 1)	12,770	25%	72,000
Settling Basin (SB 1)	5,860	100%	132,000
Waste Storage Pond (WSP 1)	12,750	100%	288,000
Waste Storage Pond (WSP 2)	48,820	100%	1,103,000

Type	Square Feet	Percent Collected	Wet Season Gal.
Wastewater Area	26,080	100%	589,000
Lightly Cont. Area	9,120	100%	206,000
Roof	9,630	100%	218,000
Roof	8,220	100%	186,000
Roof	2,820	100%	64,000
Waste Storage Pond (WSP 1)	33,850	100%	765,000

Type	Square Feet	Percent Collected	Wet Season Gal.
Waste Storage Pond (WSP 1)	16,700	100%	377,000

Wet season gallons are based on the average Oct–Mar precipitation from 2004–2023 (36.3").

Infrastructure: Precipitation Collection

Dairy

Type	Square Feet	Percent Collected	Wet Season Gal.
Wastewater Area	58,510	100%	1,322,000
Wastewater Area	3,180	100%	72,000
Lightly Cont. Area	3,870	100%	87,000
Lightly Cont. Area	27,150	100%	614,000
Lightly Cont. Area	5,730	100%	129,000
Roof **(AB 2)**	2,100	100%	48,000
Roof	690	100%	16,000
Roof	710	100%	16,000
Roof **(AB 1)**	12,510	50%	141,000
Roof **(AB 1)**	12,770	25%	72,000
Settling Basin **(SB 1)**	5,860	100%	132,000
Waste Storage Pond **(WSP 1)**	12,750	100%	288,000
Waste Storage Pond **(WSP 2)**	48,820	100%	1,103,000

Report
Manure Variables

Washington State Department of Agriculture
Nutrient Management Technical Services

Winter Storage Preparedness Estimate
Pilot Dairy

Manure Collection Variables

	Milking	Dry	Heifer
Number	370	0	200
Breed	Cross	-	Cross
Weight	1150 lbs	-	*800 lbs*
Housing	Freestall	-	Freestall
Bedding	85% Sand/Limestone, 15% Wood Shavings/Sawdust	-	Composted Solids
Waste Transfer	Scrape	-	Scrape
Separator Type	DT360 Single Press Roller	-	*None*
Sep. Efficiency	*37%*	-	-

Blue italicized text indicates a default value that stood in for missing data.

Manure Collection Variables

	Milking	Dry	Heifer
Number	370	0	200
Breed	Cross	-	Cross
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Sep. Efficiency	*37%*	-	-

Blue italicized text indicates a default value that stood in for missing data.

Meeting with Farmers

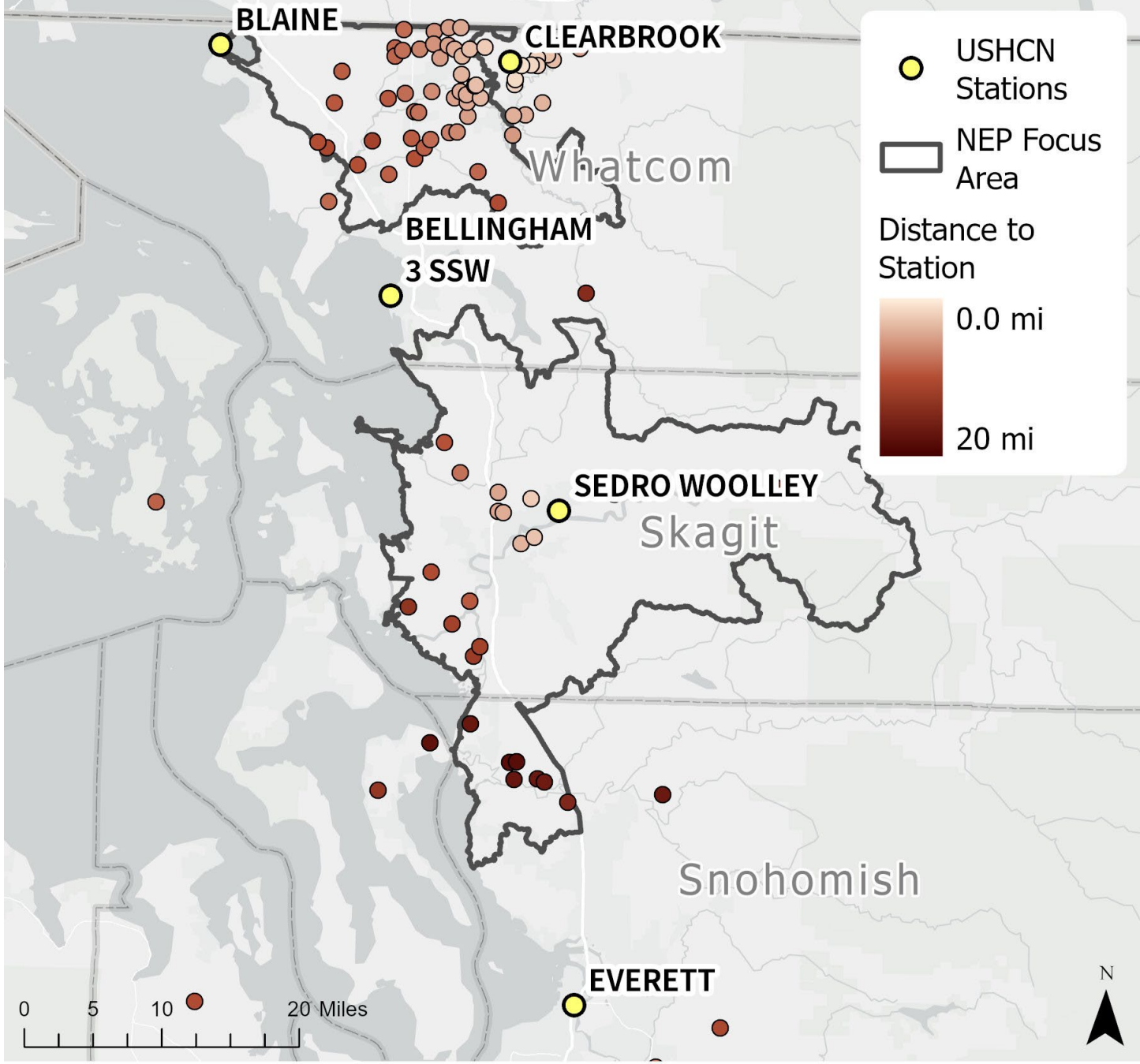
Meeting with Farmers

- Reactions
  - Interest
  - Individualized reports
  - Helps with decision-making
  - Weather stations
- Corrections
  - Cow data / gutters / % precip. collected / polygon shapes
- Barriers
  - Economic

Meeting with Farmers

- Weather Stations
  - Farmers know weather
  - 5” to 10” off in places
  - Turned some farmers off
- Annual Precip.
  - **Sedro Woolley**: 47.55”
  - **Everett**: 36.46”

  (1980-2024)



Washington State Department of Natural Resources, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community

Meeting with Farmers

- Alternative Weather Data Source
  - PRISM
    - Precipitation-elevation Regressions on Independent Slopes Model
  - Interpolated historic data
  - Fills in the gaps
  - Entire contiguous US

PRISM Group, Oregon State University, https://prism.oregonstate.edu

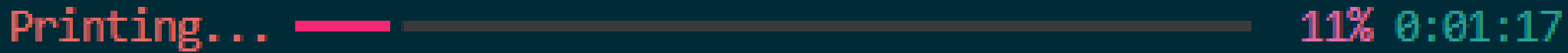
Coding Lessons

Coding Lessons

- VSCode
- Python outside of ArcGIS Pro
- pandas **DataFrame** > ArcPy cursors
  - Faster
  - Less code
  - Don’t have to loop for everything
  - Can create from ArcGIS data
- geopandas
  - pandas for spatial data

Coding Lessons

- Rasterio **sample()**
  - Only loads data from provided coordinates
  - Get data for all points at once
  - Much faster
- Multithreading with concurrent.futures
- Local version control with dulwich
- Progress bars in terminal with rich.progress



Coding Lessons
Custom Packages

- Personal Python package
  - Common methods
  - Use across projects
  - Less to remember
- Uses
  - Accessing / downloading online feature layers
  - Converting to DataFrame
  - Lists of dairies
  - WSDA color palette
  - Store ArcGIS Online item IDs

```
from custom_tools import common_methods as cm
from custom_tools import item_ids
```

```
fl = cm.get_feature_layer(item_ids.DAIRY_INFRA_DATA, layer_id=0)
```

Coding Lessons
Coding Lessons

- codewars.com
  - Coding puzzles
  - See other people's solutions

Funding Note

This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement PC-01J89801 to the Washington State Department of Health. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement of recommendation for use.

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Washington State University. AgWeatherNet. https://weather.wsu.edu

Questions

michael.lowry@agr.wa.gov

Extra Slides

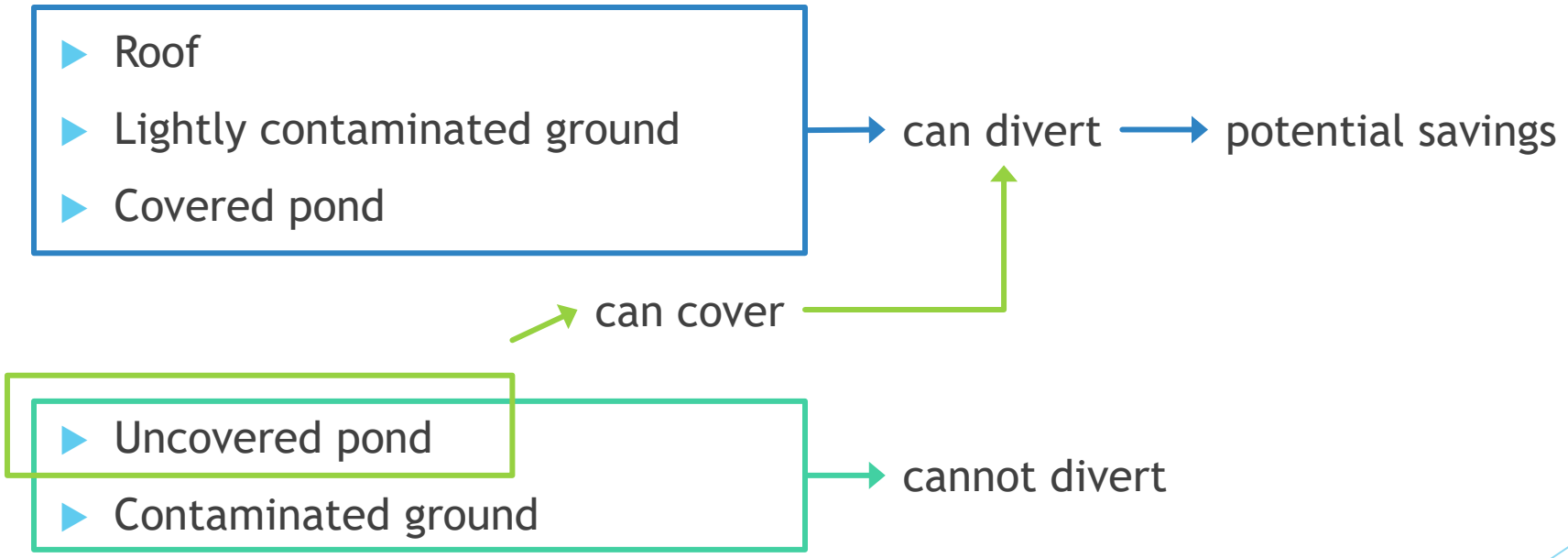
Data Sources
Climate Model

Precipitation Metrics

Annual	
Late Summer	Jul 15 – Sep 15
Heavy Event	24-hour / 2-year
Extreme Event	24-hour / 25-year
1-Inch Days	
2-Inch Days	
3-Inch Days	

Processing the Data
GIS Features

- Collected precipitation



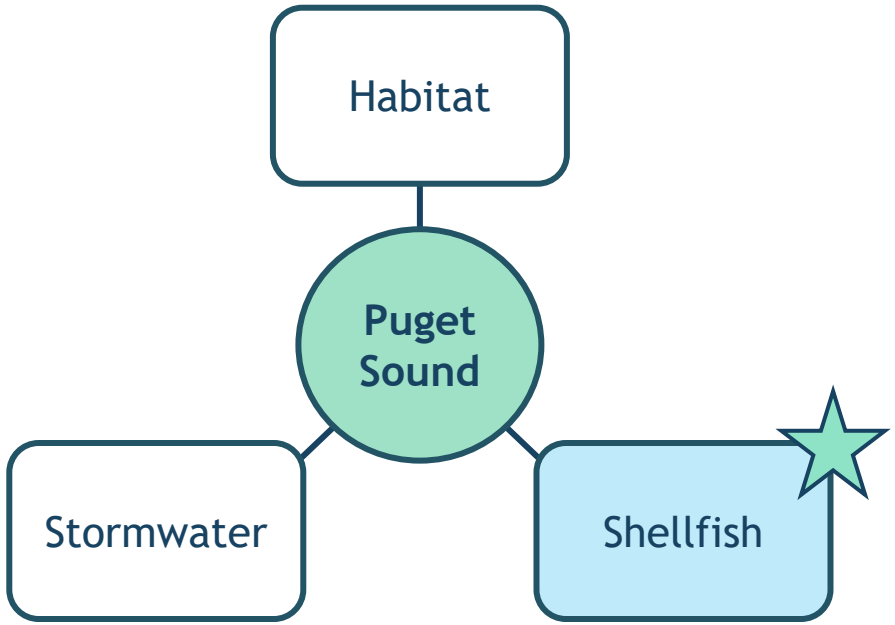
Background
National Estuary Program (NEP)

- Puget Sound
  - 2nd largest estuary in U.S.
  - 19 river basins
  - Economic, cultural & ecological importance

  - Water quality & habitat degradation
  - Population declines, risks of extinction

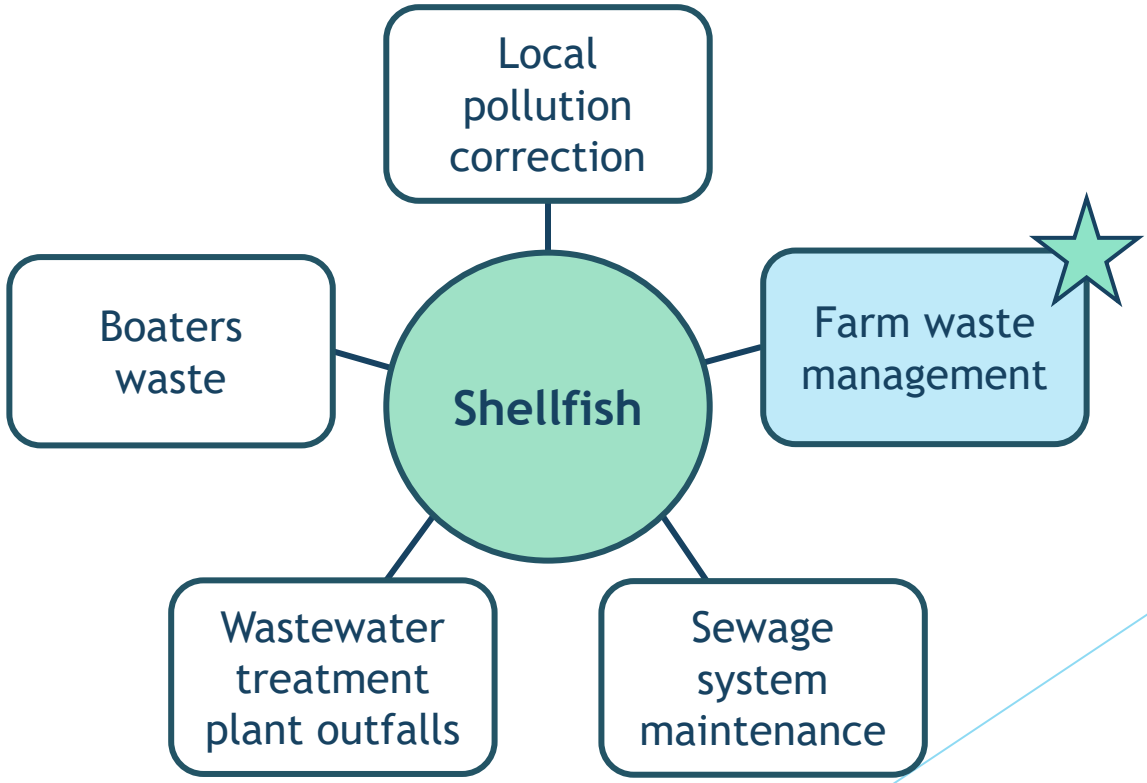
Background
National Estuary Program (NEP)

- 3 Strategic Initiatives



Background
National Estuary Program (NEP)

- Shellfish
  - Keep them safe to harvest and eat

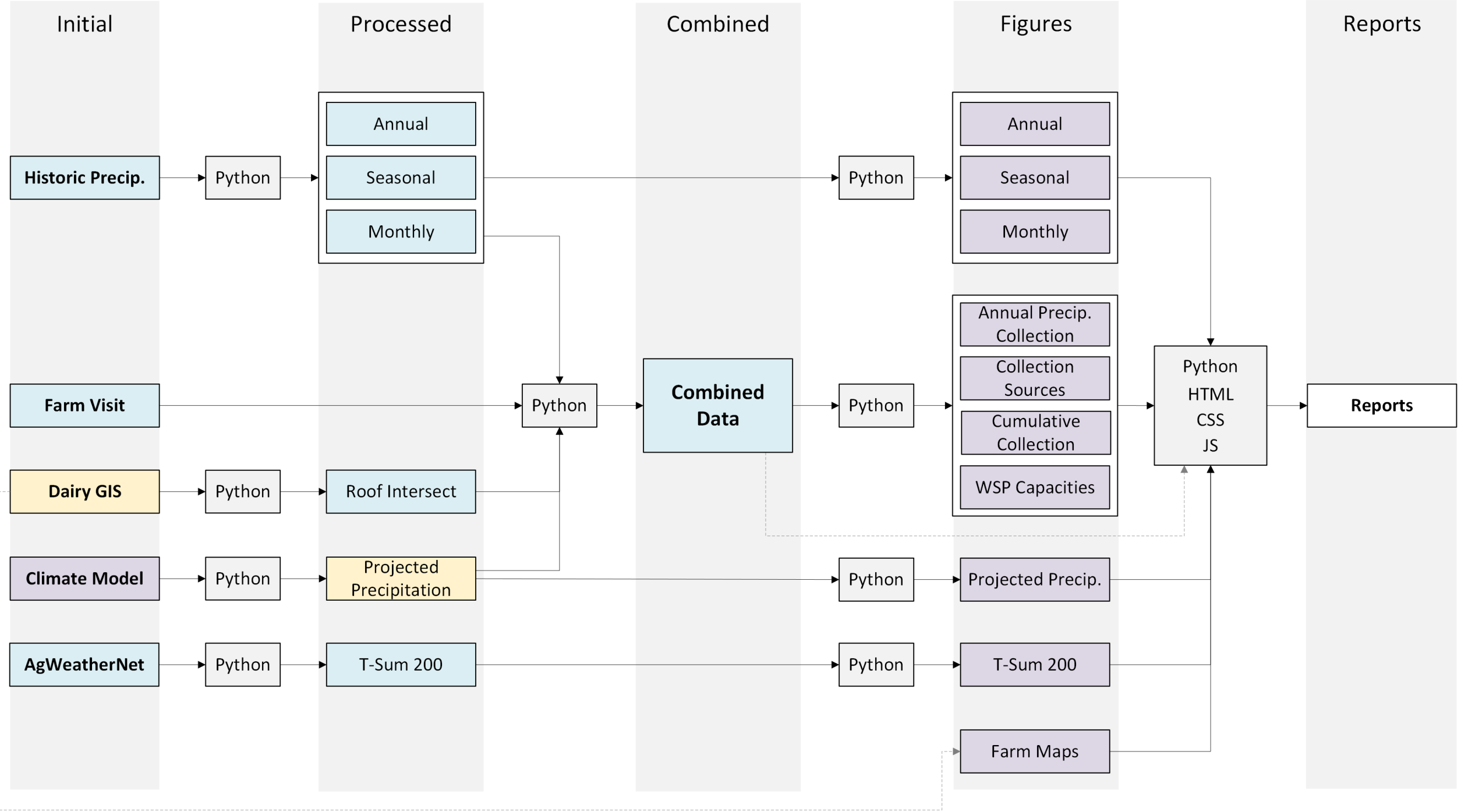


Processing the Data
GIS Features

Estimating precipitation volume

$$\text{gallons} = \text{area (ft}^2\text{)} \times \text{precipitation (inch)} \times \frac{1\text{ ft}}{12\text{ inch}} \times \frac{7.48\text{ gal}}{1\text{ ft}^3}$$

$$\text{gallons} = \text{area (ft}^2\text{)} \times \text{precipitation (inch)} \times 0.6233$$


Initial
Processed
Combined
Figures
Reports
Historic Precip.
Python
Annual
Seasonal
Monthly
Python
Annual
Seasonal
Monthly
Farm Visit
Python
Combined Data
Python
Annual Precip. Collection
Collection Sources
Cumulative Collection
WSP Capacities
Python HTML CSS JS
Reports
Dairy GIS
Python
Roof Intersect
Climate Model
Python
Projected Precipitation
Python
Projected Precip.
AgWeatherNet
Python
T-Sum 200
Python
T-Sum 200
Farm Maps