

Center for **C**omprehensive, optimal **L** and **E**ffective **A**batement of **N**utrients (**CLEAN**)

CLEAN Nutrient Center

Assessing Nutrient Management Tradeoffs and
Targets under Land Use and Climate Uncertainty

January 21, 2015
Narragansett, RI

Mazdak Arabi, CSU

JoAnn Silverstein, CU-Boulder

Brock Hodgson, CSU

Jonathan Page, NCSU



NC STATE UNIVERSITY



Mission of CLEAN

Create knowledge

Build capacity

Forge collaborations

To develop and demonstrate sustainable solutions for reduction of nutrient pollution at the system level



Our Partners

Center for Comprehensive, optimal and Effective Abatement of Nutrients (CLEAN)



Colorado State University

NC STATE UNIVERSITY

North Carolina State University

University of Colorado Boulder

University of Colorado Boulder



University of California Irvine

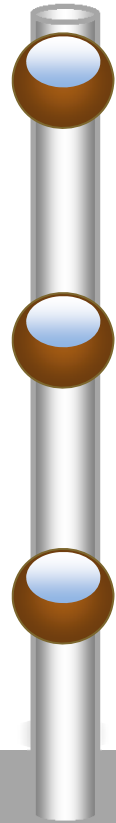
Partner Universities in CLEAN

- Metro Wastewater Reclamation
- City of Fort Collins Utilities
- Colorado Water Innovation Cluster
- City of Raleigh, Durham, Cary, and Greensboro

- EPA Region 8
- CDPHE
- USDA-ARS
- USDA-NRCS
- USDA-ERS
- USGS
- NCDENR

- Colorado Corn
- Colorado Livestock Association
- Wright Water Engineers
- HACH CO.
- In Situ.
- North Carolina Farm Bureau

Operational Goals



Develop data analysis, modeling, and decision tools (assessment & prioritization)

Develop and demonstrate sustainable solutions (wastewater, stormwater, agriculture, streams)

Identify incentives and market-based policies that enhance adoption and facilitate trading

Center Programs



- 1 Research on nutrient sources, solutions, policy, and risks
- 2 Demonstrations in different zones and at various scales
- 3 Working Groups to facilitate engagement

Center Themes

Theme I: Understanding the Physical System

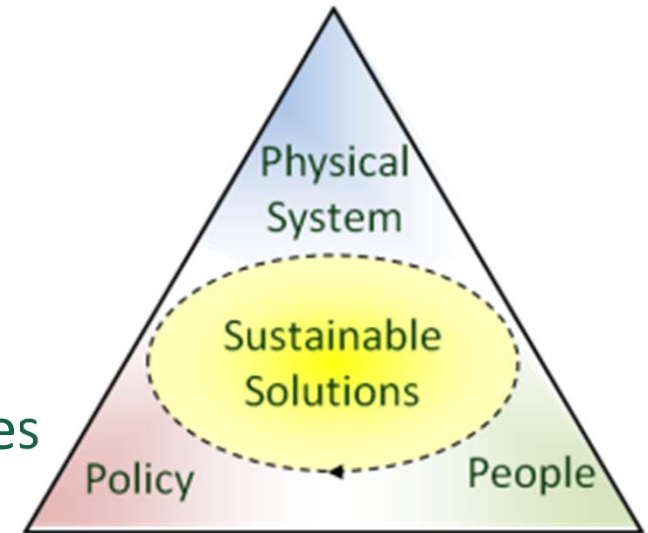
- Project 1: Urban Wastewater
- Project 2: Urban Stormwater
- Project 3: Agricultural practices
- Project 4: Fluvial Systems/Riparian Zones

Theme II: Understanding People & Policy

- Project 5: Incentives and Trading

Theme III: Assessment & Decision Making

- Project 6: Assessment Tools
- Project 7: Decision Analysis Dashboard



Study Areas

South Platt River Basin, CO

AFO: Beef and Dairy

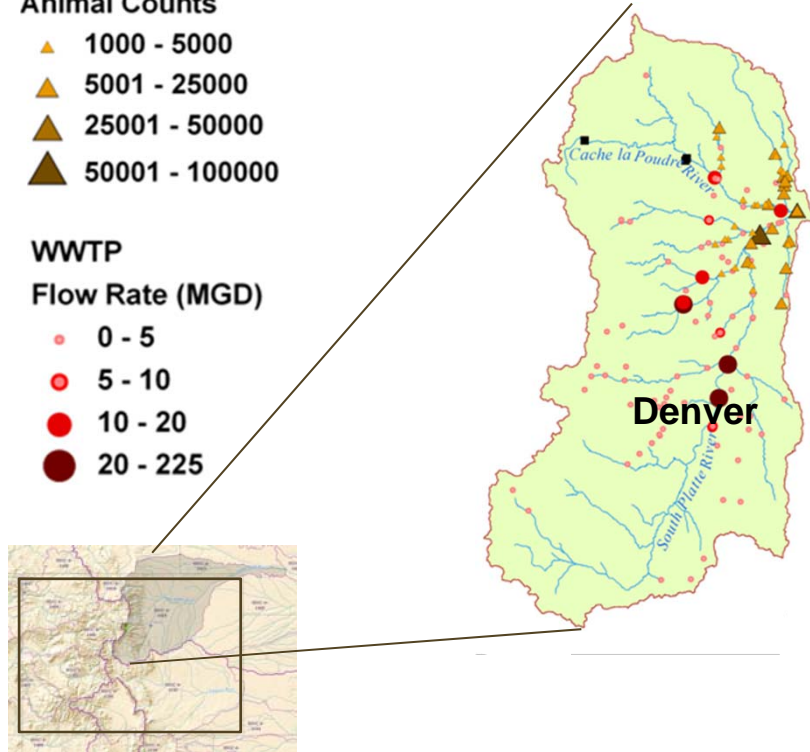
Animal Counts

- ▲ 1000 - 5000
- ▲ 5001 - 25000
- ▲ 25001 - 50000
- ▲ 50001 - 100000

WWTP

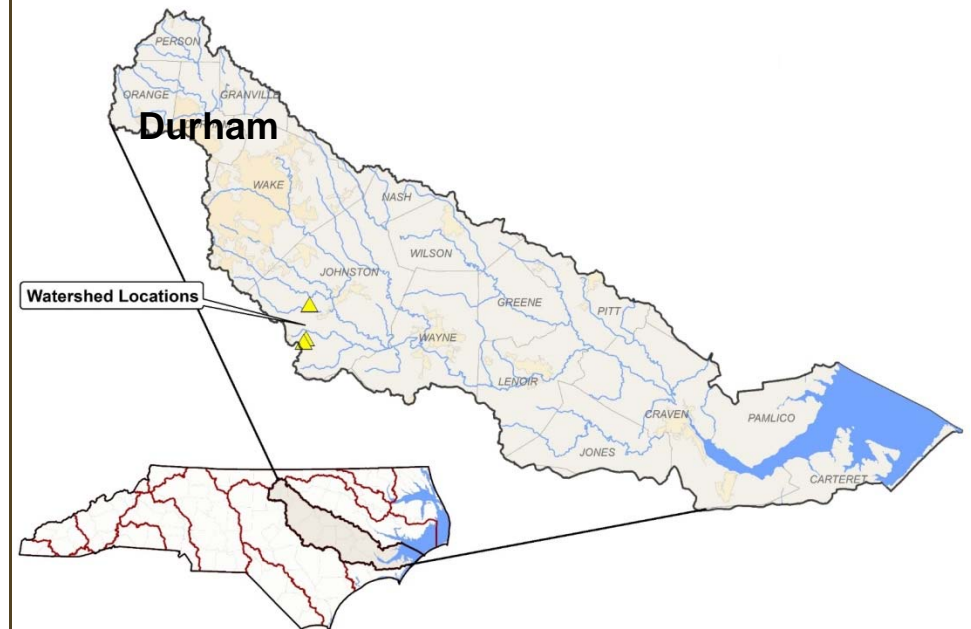
Flow Rate (MGD)

- 0 - 5
- 5 - 10
- 10 - 20
- 20 - 225

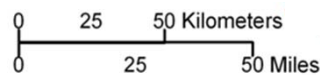


State of Colorado

Neuse River Basin, NC

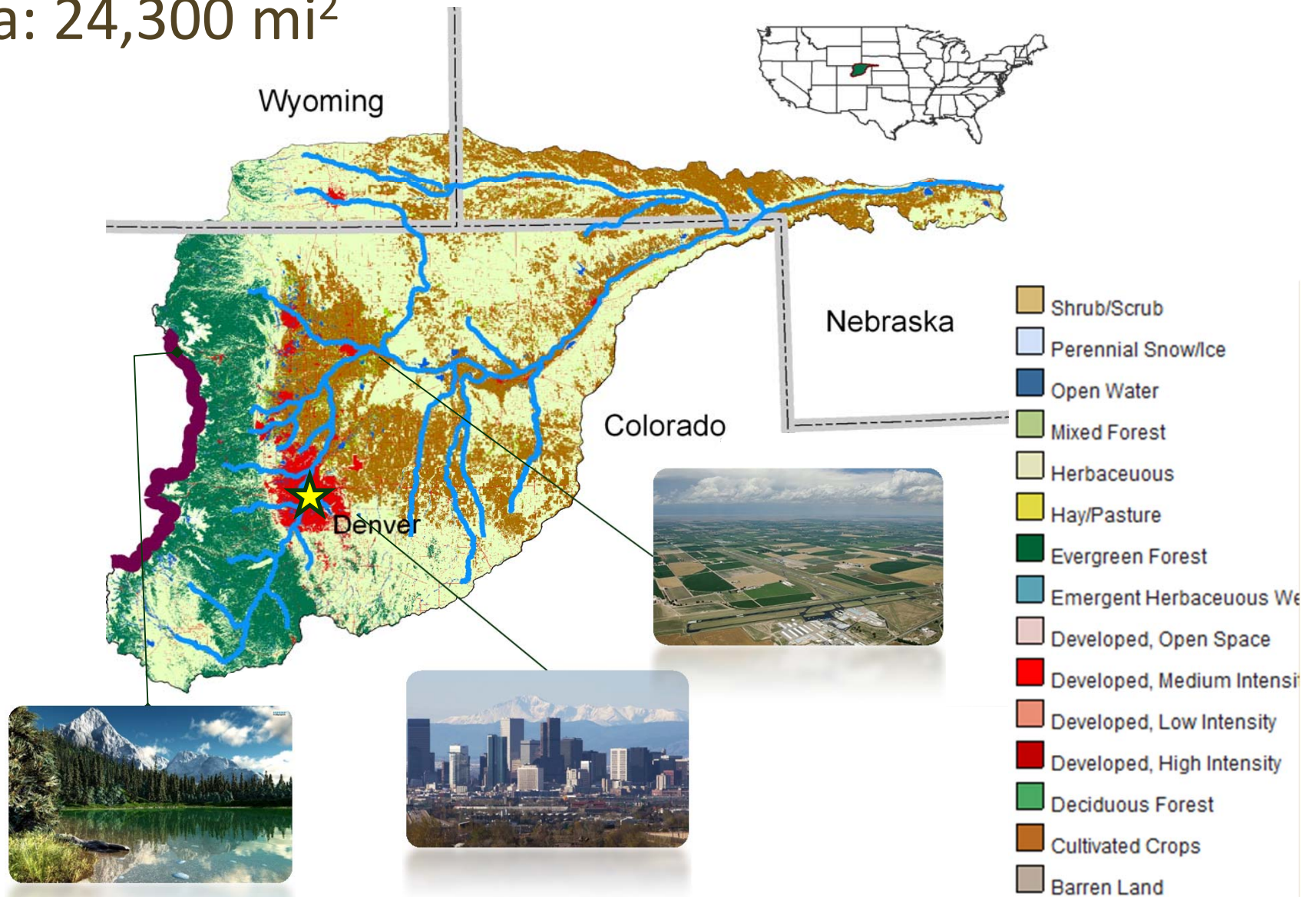


State of North Carolina



South Platte River Basin

Area: 24,300 mi²



Project 1

Assess the effects, costs and likelihood of adoption of strategies relevant to municipal water and wastewater management

Assess reliability and resiliency of solutions

- WWTP nutrient removal/recovery technologies
- Water/wastewater management

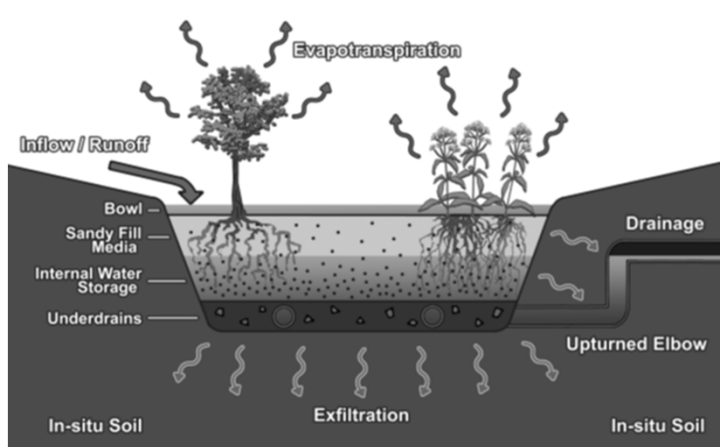


Project 2

Design and demonstrate retrofits to popular SCMs so that these modifications can potentially see widespread use across the USA



- Wet retention ponds with upflow filters
- Bioretention & internal water storage zones
- Permeable pavement, runoff harvesting



Project 3

To understand how effectiveness of agricultural conservation practices for N and P control varies with:

- Their landscape position
- Physical characteristics of the farm
- Proximity to perennial streams and irrigation ditches

To understand and characterize socioeconomic factors that influence (facilitate or impede) adoption of agricultural practices



Project 3

- Nutrient/manure management
- Tillage/residue management
- CAFO waste management
- Irrigation water management
- Fencing and cattle exclusion
- Buffer strips
- Field borders
- Grassed Waterways

Paired Watershed
Analysis

Edge-of-Field
Monitoring

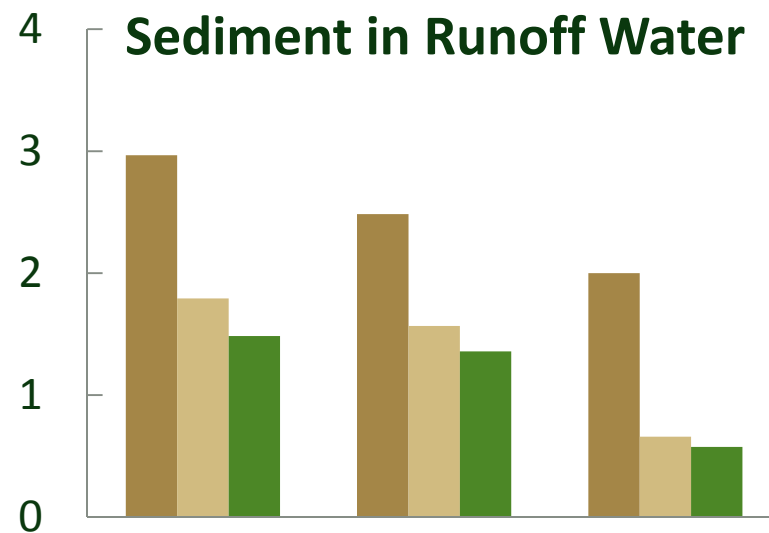
Watershed Modeling
(SWAT-CP & SPARROW)



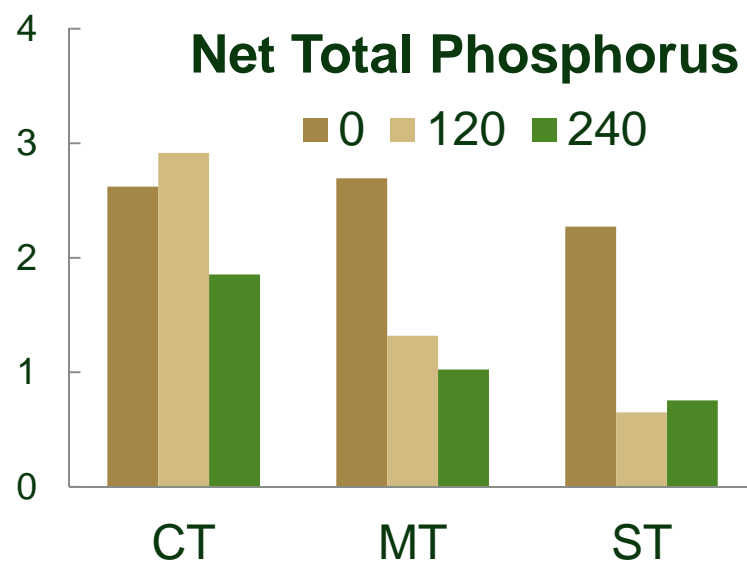
Irrigation/Tillage/ Manure



Grams of Sediment per Liter



mg/L Phosphorus



Project 4

Assess effects of fluvial erosion processes on nutrient delivery and estimate cost-effectiveness of various rehabilitation strategies

- Ecological engineering practices
- Stream/riparian restoration



Project 5

Identify effective incentives for adoption and develop context-appropriate approaches for nutrient credit trading



Likelihood of Adoption

- Incentives
- Barriers
- Institutional agreements
- Particular focus on prior appropriation vs. riparian water management doctrine



Nutrient Trading

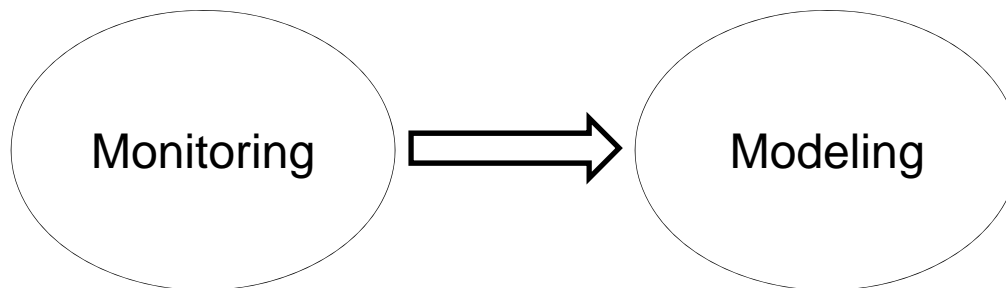
- Fixed-credit trading
- Performance-based trading



Project 6: Assessment

Develop and disseminate a nationally-applicable data-analysis and modeling system that facilitate:

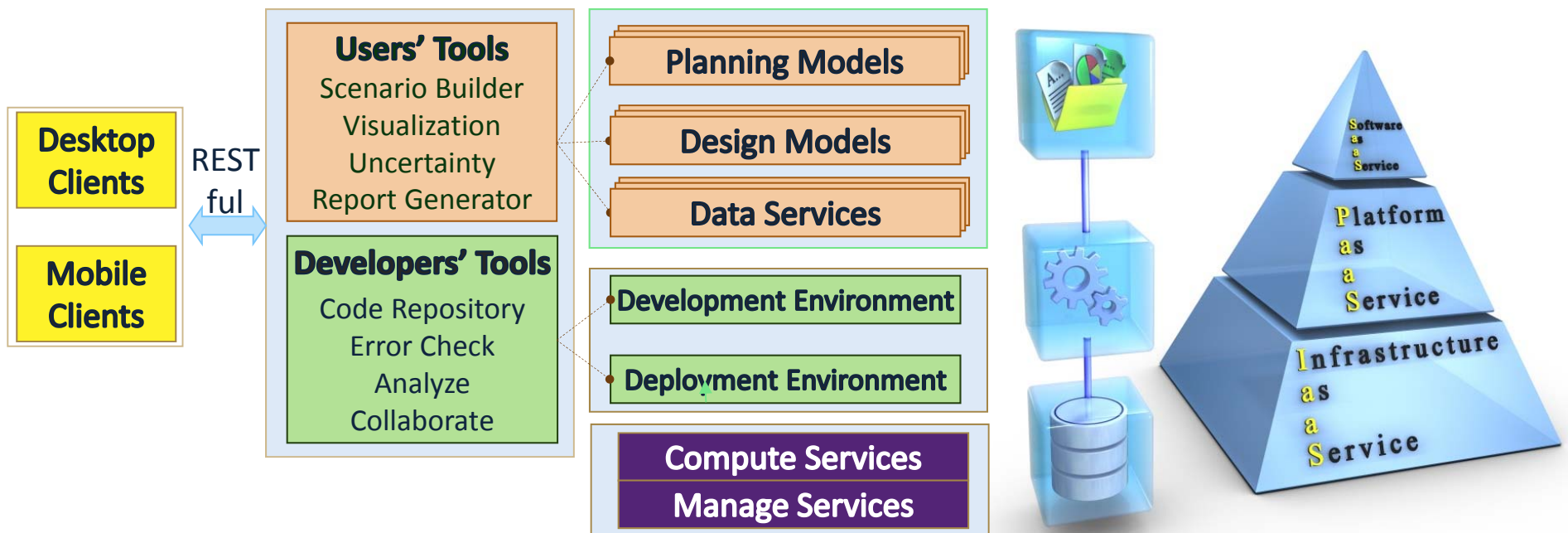
- Identify major watersheds that account for a substantial portion of N and P loads (at HUC8 or similar scales)
- Assess effects of nutrient abatement options and potential changes in land use and climate on a HUC12 or similar scale.



Project 6: eRAMS

The eRAMS technology:

- Cloud computing
- Platform-independent, highly accessible
- Computationally scalable



Physical System

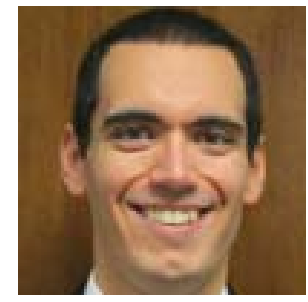
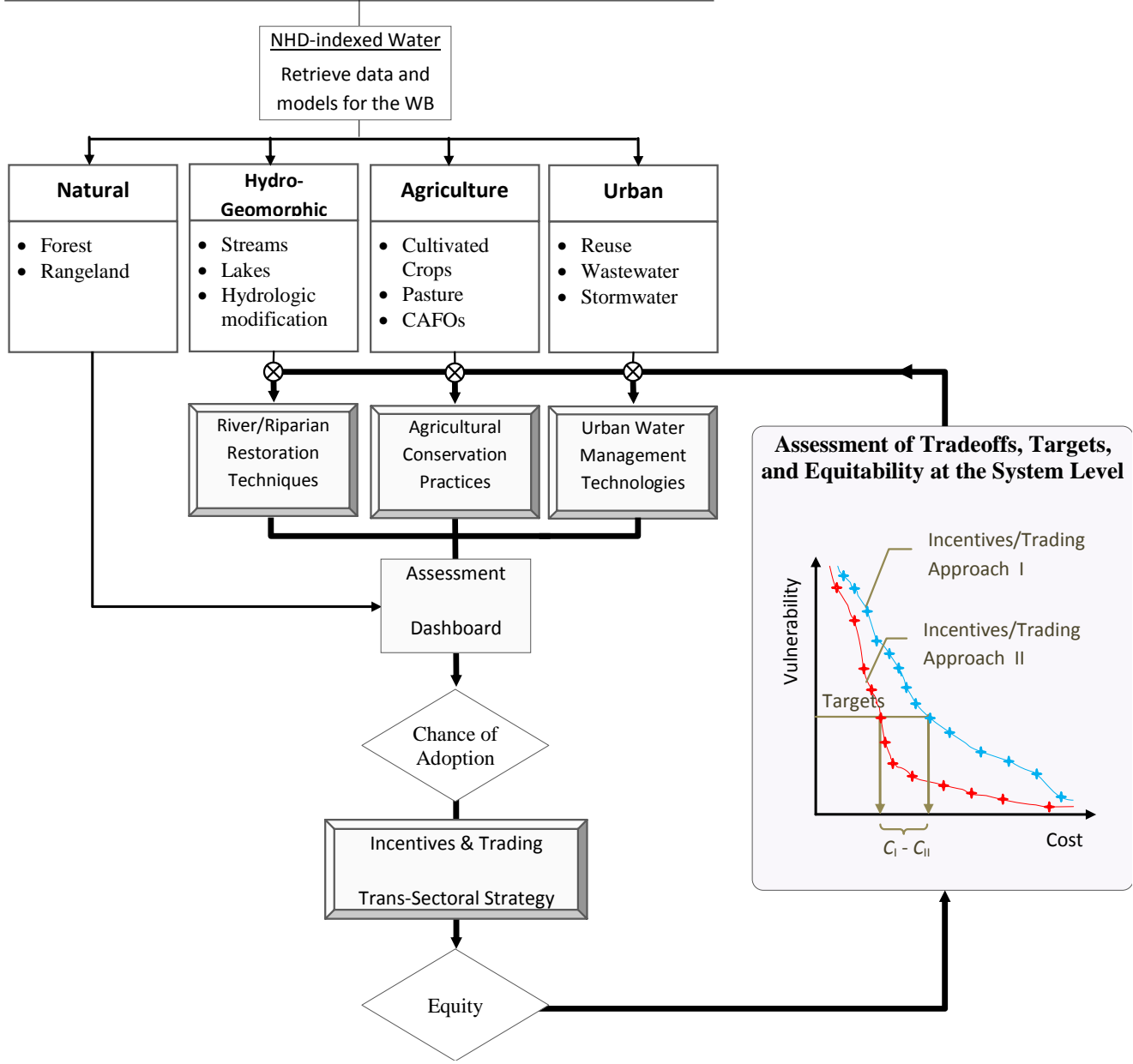
People

Policy

CLEAN Assessment Dashboard: Nutrient Data and Models for the Nation

EPA WATERS	Climate Data	WQ Data	WQ Models
- Designated Use	- NCDC	- EPA STORET	- SPARROW
- Standards	- SNOTEL	- USGS NWIS	- SWAT
- Impairments	- NEXRAD	- Private Data	- CENTURY

Integrative Framework



Project 7: Integration

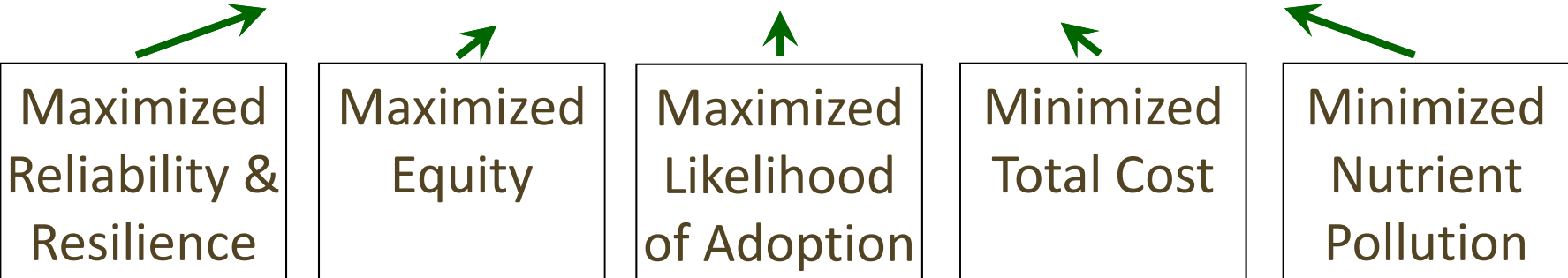


System-Level Optimal Solutions



Metrics for Integration at The System Level

MCDCA Dashboard of Total Performance



Community Engagement

Quarterly meetings with sector-specific subcommittees to learn about technological and policy research priorities.

Bi-annual meetings with the entire community to:

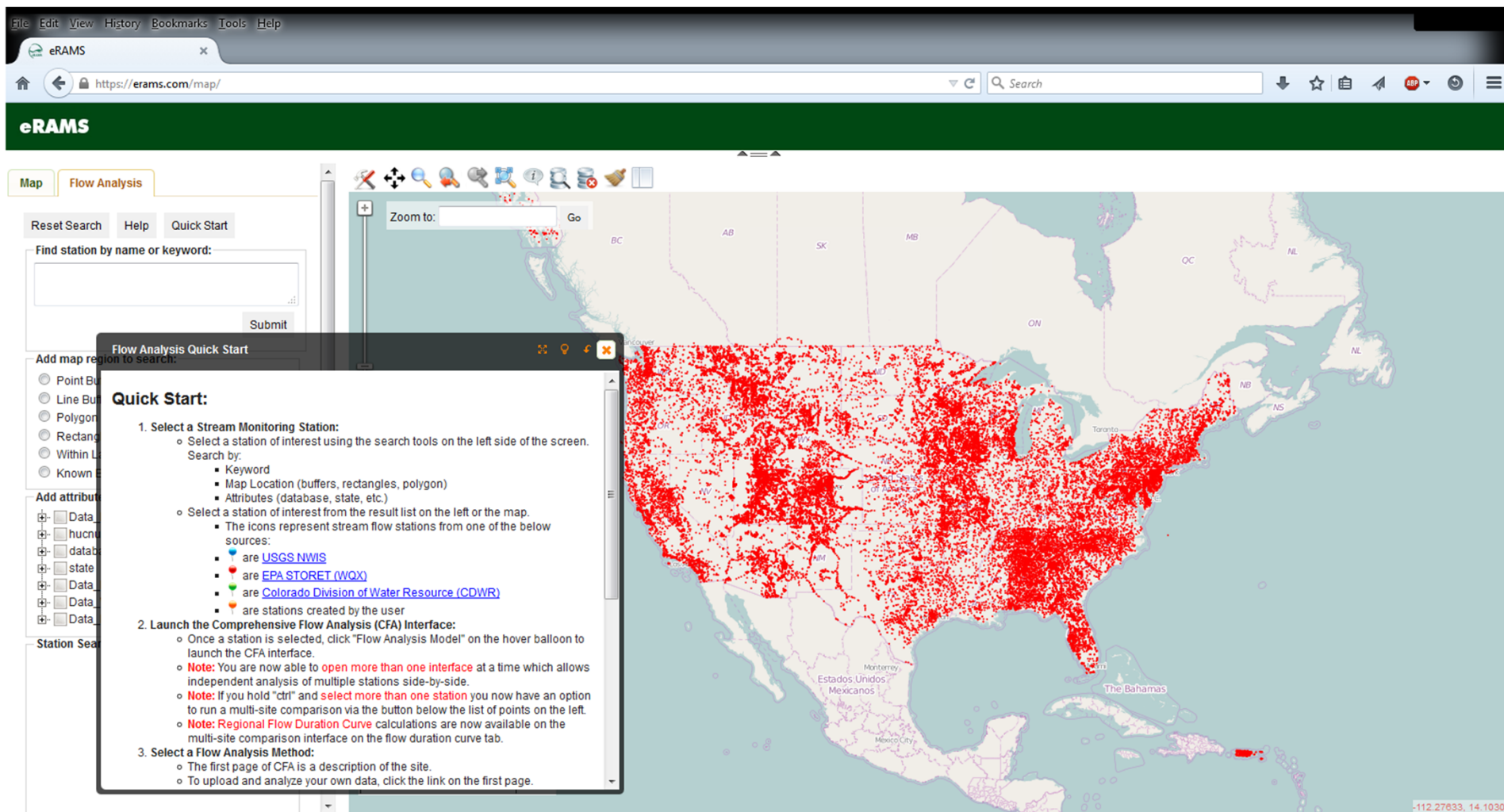
- Share successful and failed programs
- Learn from communities, regulators and managers about preferences, priorities and concerns
- Provide training on using tools and information by different sectors

Community Engagement

Working with local and state agencies to develop tools for assessment and decision analysis, e.g.,

- Prioritization of HUC12 subwatersheds within HUC8 watersheds
- Number of samples required to report compliance with targets
- Tools for permitting purposes
- Nutrient reductions benefits by technology
- Statewide water quality (decadal) assessment

eRAMS Flow Analysis



The screenshot displays the eRAMS web application interface. The browser address bar shows the URL <https://erams.com/map/>. The application header includes the eRAMS logo and navigation tabs for 'Map' and 'Flow Analysis'. A search bar is located at the top right. The main map area shows a map of North America with a dense distribution of red dots representing stream flow stations. A 'Quick Start' modal window is overlaid on the map, providing instructions on how to use the search tools and launch the flow analysis interface.

Quick Start:

- Select a Stream Monitoring Station:**
 - Select a station of interest using the search tools on the left side of the screen.
Search by:
 - Keyword
 - Map Location (buffers, rectangles, polygon)
 - Attributes (database, state, etc.)
 - Select a station of interest from the result list on the left or the map.
 - The icons represent stream flow stations from one of the below sources:
 - are [USGS NWIS](#)
 - are [EPA STORET \(WOX\)](#)
 - are [Colorado Division of Water Resource \(CDWR\)](#)
 - are stations created by the user
- Launch the Comprehensive Flow Analysis (CFA) Interface:**
 - Once a station is selected, click "Flow Analysis Model" on the hover balloon to launch the CFA interface.
 - Note:** You are now able to **open more than one interface** at a time which allows independent analysis of multiple stations side-by-side.
 - Note:** If you hold "ctrl" and **select more than one station** you now have an option to run a multi-site comparison via the button below the list of points on the left.
 - Note:** **Regional Flow Duration Curve** calculations are now available on the multi-site comparison interface on the flow duration curve tab.
- Select a Flow Analysis Method:**
 - The first page of CFA is a description of the site.
 - To upload and analyze your own data, click the link on the first page.

-112.27833, 14.10302

eRAMS Flow Analysis

The screenshot displays the eRAMS web application interface. The browser address bar shows the URL <https://erams.com/map/>. The application has a dark green header with the "eRAMS" logo. Below the header, there are two tabs: "Map" and "Flow Analysis".

The left sidebar contains several search and analysis tools:

- Reset Search**, **Help**, and **Quick Start** buttons.
- A search box with the prompt "Find station by name or keyword:" and a "Submit" button.
- Add map region to search:** with radio buttons for Point Buffer, Line Buffer, Polygon, Rectangle, Within Layer Extent, and **Known Boundary** (selected). Below this are dropdown menus for "HUC8" and "Cache La Poudre".
- Add attributes to search:** with checkboxes for Data_Flood, hucnumber, database, state, Data_Instantaneous_Discharge, Data_Water_Quality, and Data_Flow.
- Station Search Results:** showing a list of stations with colored markers: @ Prospect (red), Below Monroe (green), CACHE LA POUDRRE AT CANYON MOUTH NEAR FORT COLLINS (green), CACHE LA POUDRRE NEAR GREELEY (green), and CACHE LA POUDRRE ABOVE FORT (red).

The main map area shows a geographical view of Fort Collins, Colorado, with a large orange-shaded region. The map includes labels for "Crystal Lakes Airport", "Rashide Strip", "Mile Hi Airport", "Owl Canyon Gliderport", "Bunham Field", "Shauli Farm Airstrip", "Road Airport", "Kellogg Airstrip", "Yankee Field", "Chickman Field", "Downtown Fort Collins", "Hick Field", "Fort Collins Loveland Municipal Airport", "Windsor", "Highline Farm Airstrip", "Urbon Airport", "Creele", "Evans", "Rocky Mountain", "Estes Park", "Loveland", and "Pawnee National Grassland". Major roads like I-25 and US 87 are also visible. The map includes a scale bar (0 to 50 km) and a "Zoom to:" input field.

eRAMS Flow Analysis

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On the left side, there is a search and filter panel. It includes a "Reset Search" button, "Help", and "Quick Start" links. A search box is labeled "Find station by name or keyword:". Below this, there are options to "Add map region to search:" with radio buttons for "Point Buffer", "Line Buffer", "Polygon", "Rectangle", "Within Layer Extent", and "Known Boundary". A dropdown menu for "HUC8" is set to "Cache La Poudre". There is also a "Clear" button.

Below the search panel, there is a section for "Add attributes to search:" with checkboxes for "Data_Flow", "hucnumber", "database", "state", "Data_Instantaneous_Discharge", "Data_Water_Quality", and "Data_Flow".

The "Station Search Results:" section shows a list of stations. The selected station is "CACHE LA POUFRE RIV AT MO OF CN, NR FT COLLINS, CO".

The main map area shows a topographic map of Colorado with various geographical features. A popup window is open over a station location, displaying the following information:

- Database: USGS
- Station ID: 08752000
- Station Name: CACHE LA POUFRE RIV AT MO OF CN, NR FT COLLINS, CO
- Supervising Agency: USGS
- Latitude: 40.064426
- Longitude: -105.224427
- County: Larimer County
- State: COLORADO
- Hydrologic Unit Code: 10190007
- Drainage Area: 1054 sq. mi
- Elevation: 5220 ft NGVD29

Below the popup information, there are links for "Flow Analysis Model" and "Zoom To". A table shows data for this station:

Data Type	Begin Date	End Date	Count
Discharge	1881-07-01	2007-09-30	44468
Water Quality	1962-09-14	2002-08-07	7273
Flood	1882	2007	125
15-Minute	no data		0

The map also shows various geographical features like "South Greeley", "Livermore", "Wellington", "Pawnee National Grassland", "State Forest State Park", "Rocky Mountain National Park", "Estes Park", "Fort Morgan", and "Brush". A scale bar at the bottom indicates 50 miles and 100 kilometers.

eRAMS Flow Analysis

The screenshot displays the eRAMS web application interface. The browser address bar shows the URL <https://erams.com/map/>. The application has a green header with the eRAMS logo. The main interface is divided into several sections:

- Map:** A top navigation tab.
- Flow Analysis:** A sub-tab with options for "Reset Search", "Help", and "Quick Start".
- Search:** A text input field for finding stations by name or keyword, with a "Submit" button.
- Add map region to search:** A list of search criteria including Point Buffer, Line Buffer, Polygon, Rectangle, Within Layer Extent, and Known Boundary (selected). The "Known Boundary" section includes dropdowns for "HUC8" and "Cache La Poudre".
- Add attributes to search:** A list of attributes such as Data_Flood, hucnumber, database, state, Data_Instantaneous_Discharge, Data_Water_Quality, and Data_Flow.
- Station Search Results:** A list of search results for "CACHE LA POUVRE R NEAR GREELEY", "CACHE LA POUVRE RIV AB BOXELDER CRK NR TIMNATH, CO", and "CACHE LA POUVRE RIV AT MO OF CN, NR FT COLLINS, CO".
- Map:** A central map area showing a topographic view of the region around Laramie, Colorado. A "Zoom to:" input field is present above the map.
- Comprehensive Flow Analysis for USGS Station: 06752000; USGS:** A large configuration window with tabs for "Station", "Data", "Flood", "Drought", "Base-flow", "Duration Curves", and "LOADEST". The "Data" tab is active. It includes options for "Use Uploaded Data", "Daily Time Series" (selected), "15-minute Discharge", and "Stage-Discharge". The "Specify Analysis Period" is set from 1881-07-01 to 2007-09-30. The "Select Type of Parameter" is "Flow" and the "Select Parameter to Graph" is "Discharge -- cfs". A "Running Time Series Analysis..." progress indicator is shown in the center of the window. Below the configuration window, there are buttons for "Model Info.", "Site Info.", "Help", "Download Data", and "Run Model".
- Metadata:** A table at the bottom right providing details for the selected station: State: COLORADO, Hydrologic Unit Code: 10190007, Drainage Area: 1054 sq. mi, Elevation: 5220 ft NGVD29. Below this is a table for the "Flow Analysis Model":

Data Type	Begin Date	End Date	Count
Discharge	1881-07-01	2007-09-30	44468
- Map Data:** A footer note: "Map data ©2015 Google Terms of Use Report a map error."

eRAMS Flow Analysis

The screenshot displays the eRAMS web application interface. The browser address bar shows the URL <https://erams.com/map/>. The application has a green header with the eRAMS logo. Below the header, there are two tabs: "Map" and "Flow Analysis".

Flow Analysis Sidebar:

- Buttons: Reset Search, Help, Quick Start
- Search: Find station by name or keyword: [input field] [Submit]
- Add map region to search:
 - Point Buffer
 - Line Buffer
 - Polygon
 - Rectangle
 - Within Layer Extent
 - Known Boundary
- HUC8: [dropdown menu] Cache La Poudre
- Add attributes to search:
 - Data_Flood
 - hucnumber
 - database
 - state
 - Data_Instantaneous_Discharge
 - Data_Water_Quality
 - Data_Flow
- Station Search Results:
 - CACHE LA POUFRE R NEAR GREELEY
 - CACHE LA POUFRE RIV AB BOXELDER CRK NR TIMNATH, CO
 - CACHE LA POUFRE RIV AT MO OF CN, NR FT COLLINS, CO**
 - Cache La Poudre River above Royalder

Data Results for USGS Station: 06752000; USGS

Time Series and Statistics Results:

A time series graph is a straight scale graphing of available flow data with the oldest date on the bottom left and the most recent date on the bottom right with flows on the y axis. 15-minute (instantaneous) flow data can be useful to identify hydrographs from storm runoff for small time frames (i.e. a few days) while daily average data can be used to analyze larger trends.

Time Series for USGS Station: 06752000; CACHE LA POUFRE RIV AT MO OF CN, NR FT COLLINS, CO

Further Model Info. Print Report Download Add'l Stats Back

Data Type	Begin Date	End Date	Count
Discharge	1881-07-01	2007-09-30	44468

Map data ©2015 Google Terms of Use Report a map error

eRAMS Flow Analysis

The screenshot displays the eRAMS web application interface. The browser address bar shows the URL <https://erams.com/map/>. The application has a green header with the 'eRAMS' logo and a navigation bar with 'Map' and 'Flow Analysis' tabs. The 'Flow Analysis' tab is active, showing search options like 'Reset Search', 'Help', and 'Quick Start'. A search box is present with a 'Submit' button. Below the search box, there are options to 'Add map region to search:' (Point Buffer, Line Buffer, Polygon, Rectangle, Within Layer Extent, Known Boundary) and 'Add attributes to search:' (Data_Flood, hucnumber, database, state, Data_Instantaneous_Discharge, Data_Water_Quality, Data_Flow). The 'Station Search Results' section lists several stations, with 'CACHE LA POUDRE RIV AT MO OF CN, NR FT COLLINS, CO' selected. The main content area features a 'Data Results for USGS Station: 06752000; USGS' window. This window contains a text description of the monthly average graph, a line graph titled 'Monthly Averages for USGS Station: 06752000; CACHE LA POUDRE RIV AT MO OF CN, NR FT COLLINS, CO', and a 'Histogram Graph:' section. The line graph plots 'Monthly Average Flow [cfs]' on the y-axis (0 to 5,000) against 'Calendar Month' on the x-axis (1 to 12). It shows a peak in month 6 with a flow of approximately 4,750 cfs. The histogram graph shows a distribution of flows with a peak in month 6. Below the histogram, there are links for 'Further Model Info.', 'Print Report', 'Download Add'l Stats', and 'Back'. A table at the bottom right of the window shows the following data:

Data Type	Begin Date	End Date	Count
Discharge	1881-07-01	2007-09-30	44468

The background map shows the location of the station near Fort Collins, CO, with labels for 'Pawnee National Grassland', 'Fort Morgan', and 'Brush'. The map includes a scale bar (0 to 100 miles) and a 'Zoom To' button.

eRAMS Flow Analysis

The screenshot displays the eRAMS web application interface. The browser address bar shows the URL <https://erams.com/map/>. The main interface includes a search bar with the text "poudre", a map of the region, and a configuration window for flow analysis.

Configuration Window: Comprehensive Flow Analysis for USGS Station: 06752000; USGS

- Station:** 06752000; USGS
- Analysis Period:** Start: 1980-01-01, End: 2007-09-30
- Water-Quality Type:** Nutrient
- Water-Quality Test:** 00597 Dissolved nitrogen gas, water, unfiltered, milligrams
- Enter Water-Quality Target (mg/l):** 2
- Options:**
 - Use Uploaded Data
 - Flow Duration Curve
 - Load Duration Curve
 - Use Interactive Graphs: (20+ years of data may have troubles graphing)
 - Show Advanced Options:

Buttons at the bottom of the window: [Model Info.](#), [Site Info.](#), [Help](#), [Download Data](#), [Run Model](#)

Station Search Results:

- CRK NR TIMNATH, CO
- CACHE LA POUFRE RIV AT MO OF CN, NR FT COLLINS, CO
- Cache La Poudre River above Boxelder Creek
- CACHE LA POUFRE RIVER AT FORT COLLINS, CO
- CACHE LA POUFRE RIVER AT GREELEY WASTEWATER PLANT
- Cache La Poudre River at Lincoln Avenue
- Cache La Poudre River at Mulberry St

Map Data: Drainage Area: 1054 sq. mi, Elevation: 5220 ft NGVD29

[Flow Analysis Model](#) [Zoom To](#)

Map data ©2015 Google Terms of Use Report a map error

eRAMS Flow Analysis

The screenshot displays the eRAMS web application interface. The browser address bar shows the URL <https://erams.com/map/>. The page title is "eRAMS".

On the left side, there is a search and filter panel. The search bar contains the text "poudre". Below it, there are sections for "Add map region to search:" (with options like Point Buffer, Line Buffer, Polygon, Rectangle, Within Layer Extent, and Known Boundary) and "Add attributes to search:" (with checkboxes for Data_Flood, hucnumber, database, state, Data_Instantaneous_Discharge, Data_Water_Quality, and Data_Flow). The "Station Search Results:" section lists several stations, with "CACHE LA POUFRE RIV AT MO OF CN, NR FT COLLINS, CO" selected.

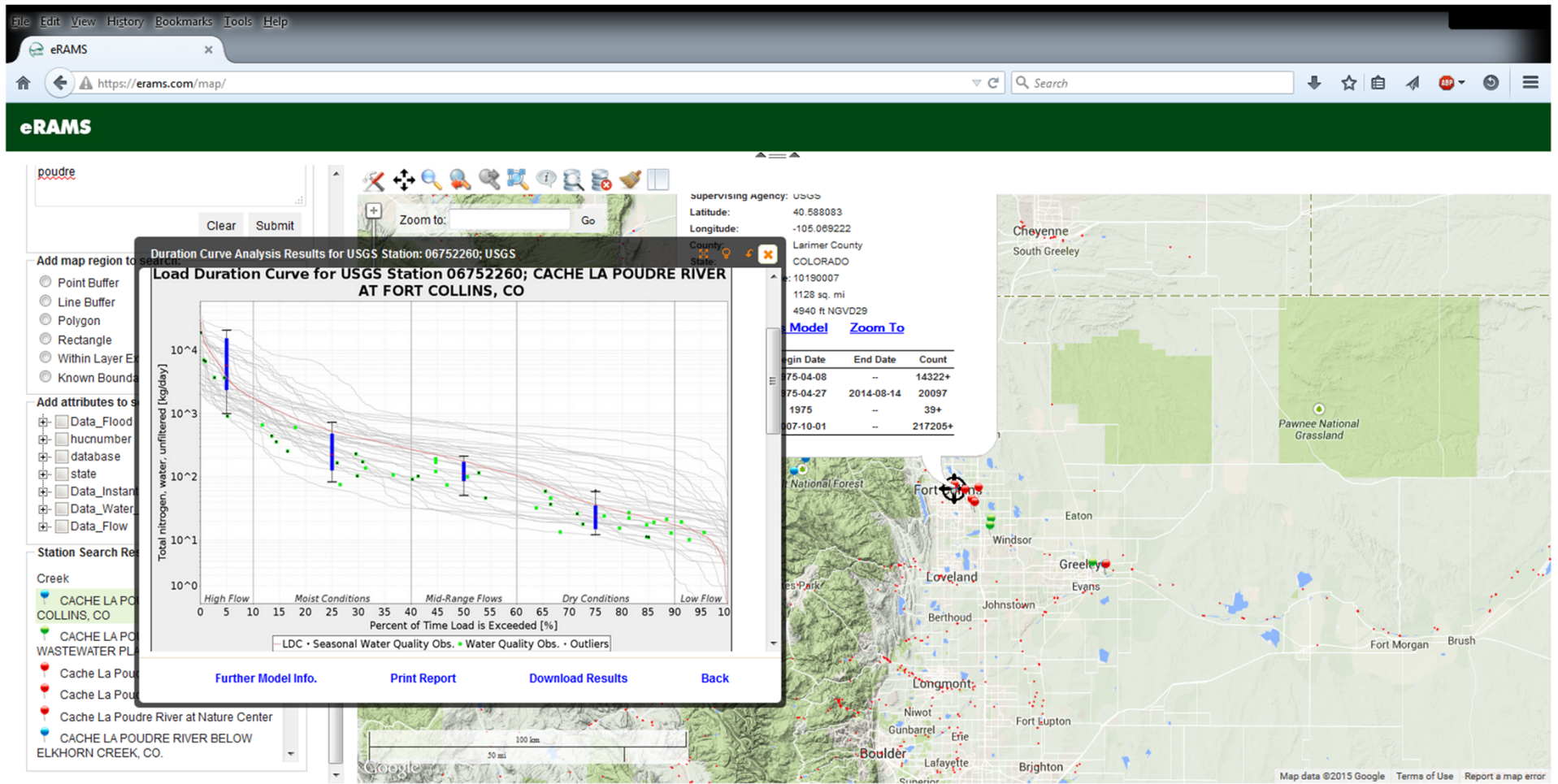
The main map area shows a topographic map of the region around Fort Collins, Colorado. A pop-up window titled "Duration Curve Analysis Results for USGS Station: 06752000; USGS" is overlaid on the map. The window contains the following text:

Duration Curve Analysis Results:
No Apparent Pollution Source:
Although some observed points may exceed the target curve's concentration there is no single apparent pollutant source. Please click 'Further Model Information' for more pollutant source identification help.

The pop-up window also features a "Load Duration Curve for USGS Station 06752000; CACHE LA POUFRE RIV AT MO OF CN, NR FT COLLINS, CO" graph. The graph plots "Total nitrogen, water, unfiltered [kg/day]" on a logarithmic y-axis (ranging from 10^0 to 10^4) against "Percent of Time Load is Exceeded [%]" on the x-axis (ranging from 0 to 100). The graph shows a series of grey lines representing model simulations and green dots with error bars representing observed data. The x-axis is divided into five flow regimes: High Flow (0-10%), Moist Conditions (10-35%), Mid-Range Flows (35-65%), Dry Conditions (65-90%), and Low Flow (90-100%).

At the bottom of the pop-up window, there are four buttons: "Further Model Info.", "Print Report", "Download Results", and "Back".

eRAMS Flow Analysis



eRAMS Flow Analysis

