Northern Integrated Supply Project
No Action Alternative Evaluation

Prepared for:

Northern Colorado Water Conservancy District

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NISP Northern Water
Northern Integrated Supply Project

Preface

MWH Americas, Inc. was contracted by the Northern Colorado Water Conservancy District and Participants in the Northern Integrated Supply Project (Consulting Services Agreement dated April 27, 2009, MWH Project No. 1006828) to develop and provide conceptual level information regarding the No Action Alternative for evaluation in the Supplemental Draft Environmental Impact Statement. This document has been prepared to fulfill reporting and documentation requirements of the agreement.

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1 Introduction

1.1 Purpose of Study

The U.S. Army Corps of Engineers (Corps) prepared a Draft Environmental Impact Statement (DEIS) for the Northern Integrated Supply Project (NISP) proposed by Northern Colorado Water Conservancy District (Northern Water) and the NISP Participants. The DEIS included a description of the No Action Alternative (NAA), or the alternative likely pursued by the Participants to meet their future needs if the Corps does not permit their Proposed Action or another Action Alternative.

Comments on the DEIS included a request for more detail on the specific features of the NAA. The Corps is preparing a Supplemental DEIS (SDEIS) to address comments. MWH was contracted by Northern Water to provide more detail on the NAA to support preparation of the SDEIS.

This study report is organized as follows.

- **Section 1 – Introduction: Description of DEIS NAA**: Approach for developing new NAA
- **Section 2 – No Action Alternative Components**: Development of water source, storage, conveyance, and treatment components (i.e., individual projects), and evaluation of their ability to meet the needs of the NISP NAA
- **Section 3 – Methods of Analysis**: Description of methods used to analyze water supply options, water quality, and project costs
- **Section 4 – No Action Alternative Options**: Development and description of three main options for meeting the NAA objectives; description of water supplies, storage requirements, conveyance requirements, and treatment requirements
- **Section 5 – Recommended No Action Alternative**: Justification for select of recommended NAA for use in SEIS
- **Section 6 – Summary**

1.2 Draft EIS No Action Alternative

The NAA in the DEIS (Corps 2008a) included different projects for different regional groups of Participants and independent projects by some Participants. Table 1 summarizes the NAA projects described in the DEIS.

Table 1. DEIS NAA Summary

Participant or Group	Firm Yield Requested (AF)	DEIS NAA Summary
Southern Group Erie Lafayette LHWD	13,200 6,500 1,800 4,900	• Not enough available agricultural CU identified to fill entire request. • Transfer 5,411 AF agricultural CU to municipal use • Purchase 15,600 C-BT Units • Storage: 10,800 AF – identified gravel pit storage
Northern Group Eaton Severance Windsor	5,900 1,300 1,300 3,300	• Transfer 5,900 AF agricultural CU • Storage: 11,800 AF – identified gravel pit
Eastern Group Fort Morgan MCQWD	4,900 3,600 1,300	• Transfer 5,100 AF agricultural CU • Fort Morgan would increase groundwater pumping and implement advanced water treatment such as RO • No storage location identified for required 6,200 AF near Fort Morgan
CWCWD Part 1: Part 2: Berthoud request in DEIS – obtained by Frederick for SDEIS	8,400 7,100 1,300	• Transfer 8,400 AF agricultural CU • Storage: 14,200 AF – identified gravel pit • Transfer 1,300 AF agricultural CU (in vicinity of Berthoud) • Storage: 2,600 AF – identified gravel pit in vicinity of Berthoud
Evans	1,600	• Transfer 1,600 AF agricultural CU • Storage: 3,200 AF – identified gravel pit
FCLWD	3,000	• Purchase 6,000 C-BT Units
Fort Lupton	3,000	• Increased groundwater pumping and implement advanced water treatment such as RO • Storage: 3,000 AF – identified gravel pit

LHWD = Left Hand Water District, MCQWD = Morgan County Quality Water District,
CWCWD = Central Weld County Water District, FCLWD = Fort Collins – Loveland Water District,
RO = reverse osmosis, AF = acre-feet, CU = consumptive use

Based on further consideration given to the DEIS NAA as part of this report, the DEIS reliance on gravel pits and Colorado - Big Thompson Project (C-BT) units as major components of the NAA is likely not feasible. The DEIS analysis of gravel pits included assumptions about the capacity of the identified pits and did not confirm their availability for purchase. In addition, the DEIS did not discuss limitations on the number of C-BT units that will be available for purchase by Participants at the time the Corps publishes its NISP permitting decision. Both of these NAA components are discussed further in section 2.1.3.

The Corps requested that Northern Water describe the NAA and its effects in comparable detail to the Action Alternatives in the SDEIS. The Corps also asked that the Participants describe their current plans in the absence of NISP, if different from the DEIS. In particular, the Corps requested the following details (Peter 2009):

- The general locations of lands for agricultural water transfer (ag transfer)

- Confirmation of the availability of storage sites
- Estimates on the volume of brine generated, possible disposal mechanisms, and anticipated energy use for treatment
- Information on water delivery infrastructure and pumping requirements

1.3 No Action Alternative Requirements

Based on MWH's experience with previous National Environmental Policy Act (NEPA) projects and discussions with Northern Water, technical and operational requirements for the SDEIS NAA were established.

1.3.1 No Corps Action

The NAA cannot include a Corps action that would result in any type of individual Corps permit. The Corps actions that must be avoided are:

- Individual 404 permits for discharge of dredge and fill material into waters of the U.S. This precludes the construction of dams on waters of the U.S. or wetlands considered jurisdictional by the Corps. The NAA could include elements that would be covered under a nationwide 404 permit.
- Any other Corps permits requiring NEPA compliance.

1.3.2 Reliability

Project reliability refers to the ability of the project to meet the firm yield requirements of the Participants, provide a similar level of drought resilience as the DEIS Proposed Action, provide a similar amount of flexibility in operations as the Proposed Action, and deliver water using proven technology. The Participants have requested 40,000 acre-feet (AF) of new reliable water supply (annual firm yield) from NISP. Firm yield requests by each Participant are summarized in Table 1. Firm yield for NISP is the minimum volume of water to be delivered to Participants during each year of the NISP hydrologic simulation model period 1950 to 2005. This model period includes several years of drought including the record drought years of 2002 to 2003. The NAA would need to provide water supply in these drought years, most likely by delivering water from carryover storage facilities. The firm yield deliveries must also account for evaporation and other losses that may occur in the system. Consequently, the average annual yield required by the identified water supplies will need to be greater than 40,000 AF.

In addition to firm yield requirements, drought resiliency is another key factor in developing and selecting the NAA. Drought resiliency pertains to the ability of the project to provide water during extreme drought conditions that are not part of the historical hydrologic study period. For typical municipal water supplies in Colorado, the inclusion of carryover storage (or storage that is filled during wet years and delivered during dry years) is a key to provide drought resiliency. With carryover storage, municipalities are able to manage a known amount of water supply during single or multi-year drought events. Without the benefits of carryover storage, water managers are forced to manage an unknown amount of water during these extreme events. The NISP

Proposed Action would provide this resiliency by having a large amount of carryover storage in the proposed Glade Reservoir.

Flexibility of operations pertains to several concepts in municipal water management, including the ability to divert water from different stream systems for water supply and water quality purposes and the ability to lease and trade water supply among NISP Participants and with non-NISP Participants. This type of flexibility provides the ability to optimize the use of available water supplies. The NISP Proposed Action would provide this flexibility by implementing a project that has the ability to divert water from two different source waters, deliver very good water quality, and allow leasing and trading amongst Participants. The NAA should have these same types of features, including multiple source waters, components that allow trading and leasing, and the ability to blend water with other water supplies to meet water quality goals.

The NAA should be based on elements proven to be successful in the Front Range of Colorado. In particular, MWH was directed to avoid concepts requiring large-scale use of RO water treatment. Although some Front Range water providers currently use small-scale RO facilities for water treatment, mechanisms for disposal of the generated brine are limited. Two different size RO treatment plants were evaluated for the DEIS Alternatives Analysis: 11 million gallons per day (MGD) and 36 MGD. Both were found to be infeasible, due to brine disposal problems, particularly the lack of maturity of zero liquid discharge (ZLD) processes (Brandhuber 2005 and Brandhuber 2006).

1.3.3 Water Quality

Treated water delivered by the Participants to their customers must meet drinking water standards. Raw water obtained for the NAA could be of lower quality than the raw water delivered by the Proposed Action, meaning that additional water treatment may be required. Any additional treatment required to meet water quality standards or the Participants water quality goals, above and beyond that required for treatment of raw water supplied for the Proposed Action, is documented for the NAA.

A major benefit of the Proposed Action for the Participants is that the water could be treated in their existing WTPs, which, for the most part, use conventional water treatment technology. In the Participant meetings the Participants expressed the need to deliver high quality water to their customers and to deliver water comparable to their existing finished water. Northern Front Range water sources diverting farther downstream than existing supplies will most likely require additional water treatment to meet drinking water standards and be comparable to the quality currently delivered to customers.

Total dissolved solids (TDS) is substantially higher in some potential NAA source waters than in the Participants' current source waters and is challenging to treat. For planning purposes, an upper limit TDS goal of 400 milligrams per liter (mg/L) in finished water was set for the NAA. This concentration is less than the secondary water quality standard of 500 mg/L, but is consistent with TDS goals used by other Front Range municipalities. This is discussed further in Appendix B.

1.4 No Action Alternative Development Process

Discussions with Northern Water and the Participants revealed that the DEIS NAA was not feasible particularly due to its reliance on gravel pit storage, C-BT unit purchases, and groundwater use, and that substantial changes to the DEIS NAA were needed. In order to maintain consistency, the NAA development process was based on the alternatives development process in the DEIS with some modifications. A flowchart of the process used to develop the NAA is presented in Figure 1.

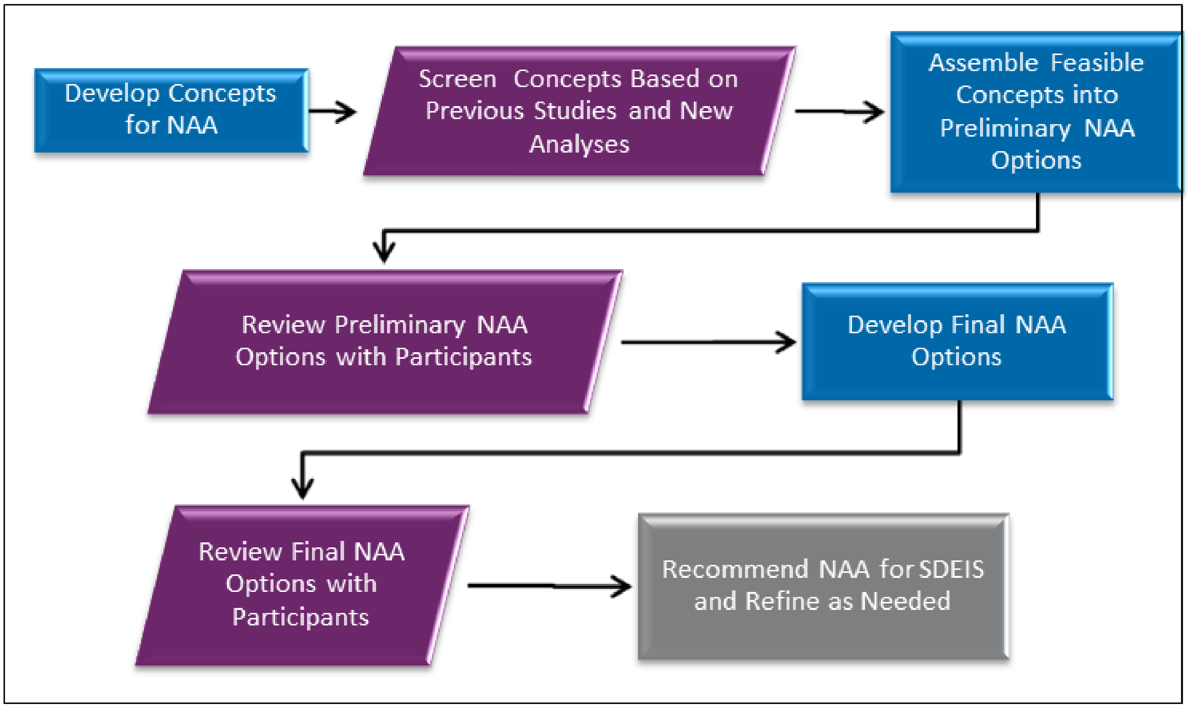


Figure 1. Process for Developing the NAA

The NAA will be composed of four basic components: water supply, storage, conveyance, and water treatment. The DEIS did not consider various methods to convey or treat water at the alternatives development stage. Because both of these were important to the NAA development process, they were also analyzed.

In general, because water supply and storage locations are limited in northern Colorado, the NAA development process began with identifying potential water supply and storage components and then identifying conveyance and water treatment required to deliver water of adequate quality to the Participants. Potential concepts were identified from the NISP DEIS Alternatives Evaluation Report (HDR 2007), the WGFP: Alternatives Report (Reclamation 2005), and discussions with Northern Water staff and the Participants. Where possible, information from the DEIS and the other documents was used to screen concepts. Based on direction from Northern Water, no formal numerical ranking or scoring process was used in the screening processes. Screening was performed on a qualitative basis using existing or new technical information developed as part of this study.

Once initial development and screening of concepts was completed, retained concepts were assembled into several NAA preliminary options that could meet the Participants requested firm yield requirements. Five preliminary options were developed. At this point, the preliminary options did not contain specific storage locations or pipeline alignments, just general locations. These preliminary options were presented to the Participants in individual and group meetings and presented to Northern Water staff for review.

Feedback received from the Participants and Northern Water staff and additional technical review were used to select and refine three of the preliminary options into final NAA options. The three final NAA options identified specific storage locations, as well as quantified the amount of yield, conveyance capacity, and treatment required for the option to meet the NAA requirements.

The three final options were discussed with the Participants and Northern Water. A comparison of the benefits and drawbacks of the options lead to the selection of the recommended NAA.

1.5 Participant Meetings

MWH met with each of the Participants in June 2009. Topics of discussion included existing water systems, Project Participant ideas for components and the NAA, and NAA preliminary options developed by MWH. Notes were prepared for each meeting and are on file with Northern Water. The following general information was gathered during these meetings:

- Water quality and ability to meet firm yield requirements are the most important aspects of the NISP. Any NAA should strive to deliver water of the same quality that is expected to be delivered by the NISP Proposed Action, which for the southern and eastern Participants (see groupings in Table 1) is the quality of Carter Lake and for the northern Participants is the quality of Horsetooth Reservoir.
- None of the Participants like the idea of large-scale ag transfers, as many of the Participants' communities and economies are agricultural. However, the Participants realize that this is the most reasonable and likely source of future water supply absent the NISP Proposed Action.
- Based on previous water transactions and Boulder County and City of Boulder Open Space Programs, substantial ag transfers from Boulder County as part of the NAA are unlikely.
- Regional projects including shared storage and water treatment would be considered if NISP could not be constructed. Most Participants would prefer to use their existing treatment facilities, but, based on the location of the available water supplies, new regional treatment facilities may be more practical for the NAA.
- Although not preferred, Reverse Osmosis (RO) treatment would be considered as a means to treat water to meet target water quality levels.
- Generally, alluvial well water is not an available water supply option either due to augmentation requirements or because of water quality issues (such as radionuclides or nitrate) that would require extensive treatment and pose challenges with residuals disposal.

During interviews, some of the Participants shared ideas for individual or small group projects for the NAA. The ideas were generally not fully formed solutions that included all required components (i.e., source water, storage, conveyance, and treatment). Many Participants expressed interest in a potential alternative concept that included agricultural transfers and working with adjacent NISP and non-NISP water suppliers for shared conveyance and storage. For instance, Lafayette described the possibility of working with LHWD and Erie to obtain water through ag transfers, divert and store water in a potential reservoir or gravel pit near St. Vrain Creek and I-25, and either treat the water in a new regional plant or deliver raw water to their existing facilities. Erie had several ideas, including sharing capacity in the current Gross Reservoir expansion or working with other water providers to develop new storage in the foothills.

1.6 Development of the NAA as a Regional Project

The NISP NAA should consist of activities or projects the Participants would likely pursue to meet the portion of their future water demands planned to be met by NISP if NISP were not permitted. There are several possibilities for the 15 Participants to meet future water demands. These fall into three general strategies: (1) each Participant acts individually to develop the necessary water supplies and infrastructure; (2) Participants form sub-regional groups of about two to four entities, similar to the alternative described in the DEIS; and (3) Participants develop one or two regional projects where all Participants would share ownership, water supplies and infrastructure capacity. As described in the previous section, the Participants have not made firm plans for how they would proceed with water supply development if NISP is not permitted, so reasonable assumptions based on professional judgment were necessary in formulating a NAA for the SDEIS. However, the Participants have expressed interest in pursuing regional solutions that would provide operational efficiencies and cost savings.

Comparing conceptual individual Participant NAAs to a conceptual regional NAA led to developing final NAA options that are regional in nature. Large regional projects are more efficient than small individual projects in terms of the amount of ag transfers required and infrastructure cost. The following rationales directed the NAA analysis toward the development of regional water projects.

- Municipal and industrial water suppliers along the northern Front Range have a history of successfully developing regional projects. Examples of regional projects include the Colorado-Big Thompson Project, the Windy Gap Project, the Southern Water Supply Pipeline, the Windy Gap Firming Project, the Soldier Canyon Filter Plant, the Carter Lake Filter Plant and NISP itself.
- A regional project would result in less ag transfers than multiple smaller projects. Multiple smaller projects would require additional water supply due to increased evaporative losses from multiple smaller reservoirs (see Section 2.2). In addition, the systems may lose efficiency due to smaller less diverse water supplies and the inability to trade between Participants.
- A regional project could be constructed and operated at a lower unit cost to obtain the required 40,000 AF of firm yield than multiple smaller projects. Cost estimating performed in the NISP Phase II analysis shows that multiple smaller pipes conveying the

same amount of water as a single larger pipe will have a higher total cost for construction (MWH 2004). For example, two 42-inch pipes have approximately the same capacity as one 60-inch pipe but the cost is about 13 percent greater (Integra Engineering and GEI 2010a). In general, the development of multiple smaller reservoirs would cost more per AF than a single larger reservoir. As an example, the DEIS includes a cost of $48 million for a 40,000 ac-ft Galeton Reservoir and $28 million for a 20,000 ac-ft reservoir; the unit cost of the larger reservoir is $1,200/ac-ft compared to $1,400/ac-ft for the smaller reservoir.

- A regional project provides access to higher quality water supplies for the southern and eastern Participants than what they could reasonably acquire in an individual project (discussed further in Section 2). The ability for the southern and eastern Participants to acquire high quality water supplies in the upper Big Thompson and Poudre Basin through a regional project provides a more attractive alternative than individually developed supplies.
- NISP only provides a portion of each Participant's total future water supply need. Each Participant will continue to develop smaller local water supplies to fill the gap between future demand and that portion of future demand supplied by NISP. Therefore, using smaller local supplies as an alternative to NISP is not feasible for many Participants because the supplies are already planned to be developed in addition to NISP.

A NAA composed of smaller projects implemented by individual Participants or small groups of Participants would have the following characteristics:

- As described in further detail in Section 2.1, ag transfers would be the primary water source for any NAA. The acreage affected by ag transfers when several smaller facilities are used would increase by to 2,000 to 3,000 acres compared to a regional alternative.
- It is likely that the location of ag transfers would be more scattered, with increased transfers from smaller irrigation systems, especially those in which the Participant is already a share-holder.
- Many smaller storage facilities would be used rather than a few larger reservoirs. The analysis described in Section 4 indicates that one to three AF of storage would be required for each AF of firm yield. The amount of storage is largely dependent upon the location and water rights of the acquired supply. If the Participants were to pursue smaller storage alternatives, and assuming an average reservoir size of 5,000 AF, 8 to 25 new reservoir sites would need to be developed. It is likely that these sites would be a mix of gravel pit storage along the lower portions of the Big Thompson and St. Vrain rivers and along the South Platte River, and new upland reservoir sites located relatively near the agricultural water supply sources.
- Because exchange potential along rivers in the study area is unreliable for new junior exchange rights, any water supplies from ag transfers would need to be pumped and piped from the lower reaches of the tributaries and the South Platte back to the Participants. This would require more piping infrastructure than that needed for a regional alternative. Each Participant or sub-group of Participants would require

pipelines from storage back to their water treatment plants, which are typically located along the foothills. This could result in essentially parallel pipelines from similar points of origin to similar destinations.

- Because water supplies for many of the Participants would likely be obtained from poorer quality sources in the lower tributaries and South Platte, RO treatment facilities would be required for those without adequate blending water sources.

In summary, a regional alternative was identified as a reasonable future action by the Participants in the absence of NISP due to the precedence of regional projects within Northern Colorado, efficiencies in operation and cost, and access to higher quality water supplies. If smaller sub-regional or individual projects were developed, the primary difference from the regional alternative would be smaller but more storage facilities, and increased conveyance and treatment infrastructure. Ag transfers would remain as the primary water supply, with an increase in the amount of acreage affected.

2 No Action Alternative Components

As described in Figure 2, the NAA will be composed of four basic components: water supply, storage, conveyance, and water treatment. Within each of these components are several potential elements for meeting the requirements of the component. Elements within each component were analyzed and screened based on the analyses conducted in previous EIS and alternative evaluation studies and based on experience with Northern Colorado water planning issues. The following sections summarize the components, elements, and screening results. Throughout this section, unless specifically discussed herein, the concepts and elements screened and eliminated as part of the DEIS alternatives analysis were eliminated for the same reasons as part of the NAA development. See Section 4.2 of the DEIS Alternatives Report (HDR 2007) for more information on the screening process.

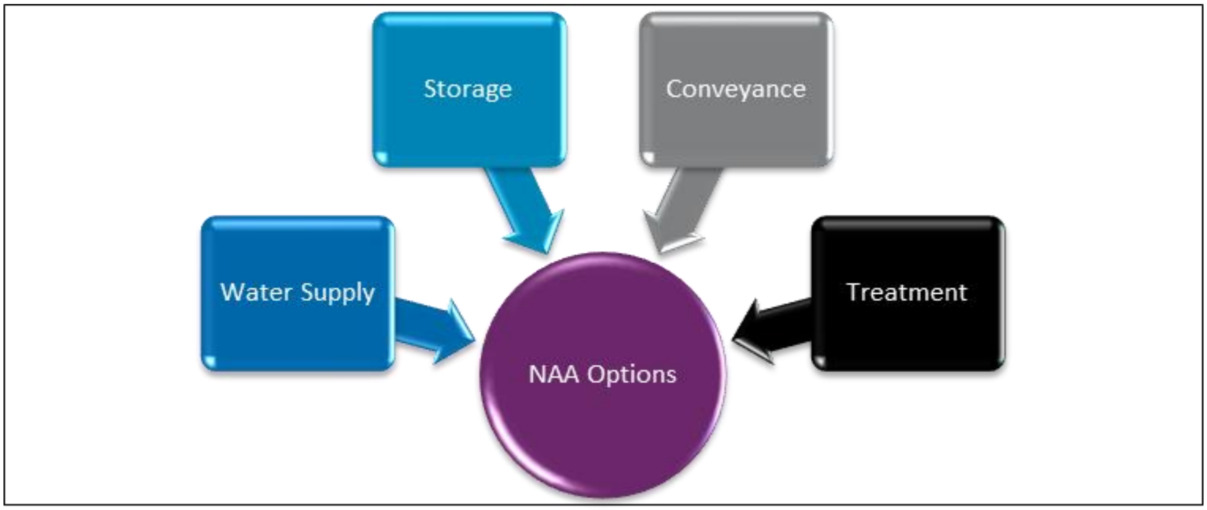


Figure 2. NAA Components

2.1 Water Supply Component

Water supplies pertain to the physical sources of water from which water supply yield would be provided to the NAA. The DEIS considered and eliminated numerous other water supply concepts as part of the alternatives development process (HDR 2007). A review was conducted of these concepts (both those retained and those eliminated) as part of the NAA development.

2.1.1 Native Water Rights

Development of native water rights would involve the development of new water rights on streams and rivers that are in the vicinity of the Participants' existing water supply portfolios. This primarily includes development of water rights within the Cache la Poudre, Big Thompson, St. Vrain, and Lower South Platte basins. This geographic extent is consistent with the geographic area considered in both the Phase II analysis and the DEIS. The Participants would not look beyond this geographic extent for water supplies in absence of the NISP. Because both the Phase II analysis and the DEIS fully considered development of native water rights within these basins, all information contained in these sections was taken from these documents.

As envisioned and analyzed in the DEIS, NISP would develop Northern Water's existing decreed Grey Mountain conditional water right on the Cache la Poudre River under a May 2, 1980 priority. Under a NAA, this water right would not be developed for the Participants because it is likely that Northern Water would continue to pursue development of this water right for other uses. Additionally, several other major conditional water rights exist on the Cache la Poudre River, including conditional storage rights by the City of Fort Collins for an enlarged Halligan Reservoir, junior conditional direct flow water rights by the City of Thornton in its 1988 water court case, conditional storage rights by the City of Greeley at Milton Seaman, and conditional storage rights owned by the Tri-Districts (Soldier Canyon Filter Plant) and the City of Greeley for gravel pit storage. Together, these rights total approximately 100 cfs (not including diversion rights for off-channel storage and hydroelectric generation) and 283,000 AF of storage. Information in the Phase II analysis Tech Memo 3 (Scott and Paulson 2003), which considers a study period of 1950-2001, reports average annual flows at the Cache la Poudre at Canyon Mouth gage of 232,000 AF, and a maximum annual flow of approximately 650,000 AF. Average annual diversions within the Poudre basin were reported as nearly 360,000 AF. Based on this information, and assuming a junior water right, development of native flows within the Cache la Poudre Basin could not support on their own the NAA yield requirements. However, in development of the NISP NAA, it was assumed that a junior water rights filing would be made on any new storage facility developed as part of the NAA to supplement other water supplies.

Development of native water rights in both the St. Vrain and Big Thompson basins was also considered in the Phase II analysis. Storable flows were estimated for both basins in the Phase II analysis Technical Memorandums 5E (Fardal 2004) and 5F (Fardal 2003). Based on information in these documents, development of native flows would not be economically efficient, and thus could not supply a major portion of the NISP yield requirements. However, as in the Poudre basin, it is assumed in development of the NISP NAA, that a junior water rights filing would be made on any new storage facility.

The Phase II analysis and subsequent hydrologic investigations performed as part of the DEIS show that there is a much larger frequency and volume of unappropriated flows on the lower South Platte than the tributary basins. These unappropriated flows are the source of water for the South Platte Water Conservation Project (SPWCP) portion of NISP. Neither the Phase II analysis nor the DEIS considered lower South Platte water as a direct potable supply for NISP because of water quality issues. However, these supplies were reconsidered as part of the NAA with the assumption that they could potentially be blended with other water supplies to provide more acceptable water quality, could be used as part of an expanded non-potable (dual-use) system (see Section 2.3.4), or could be treated with advanced treatment (see Section 2.4.2). In addition to the water rights held by Northern for the SPWCP, there are many other conditional water rights that could rely on this unappropriated flow. It is unknown how many of these conditional water rights would be developed in the future and what their effect on unappropriated flows would be. Based on this information, it was assumed that a junior water rights filing could be made as part of the NISP NAA, and as described in subsequent sections, although these rights would not provide the major supply for an option, they could potentially provide a larger portion of the required NISP yield than junior water rights in the tributary basins.

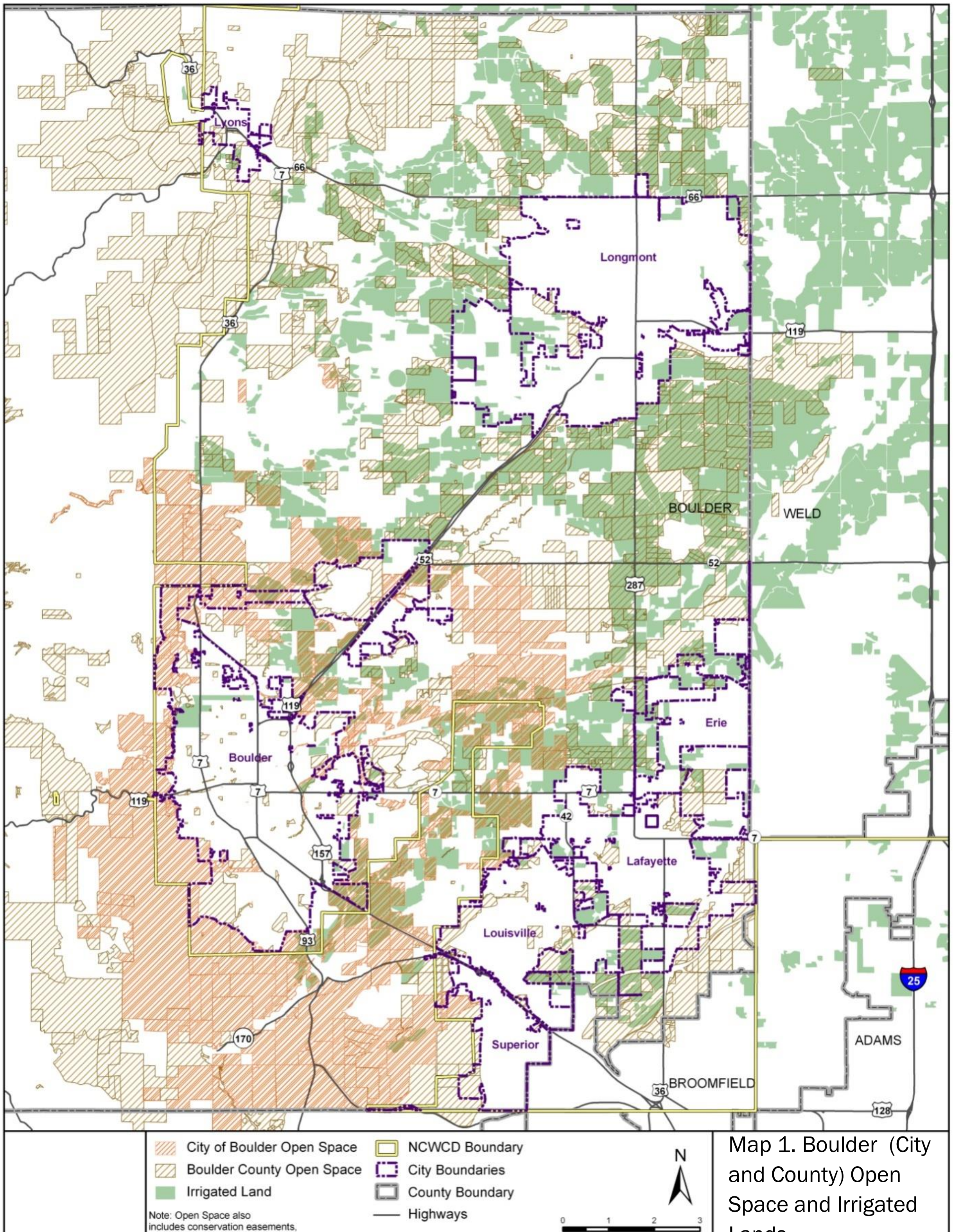
2.1.2 Agricultural Water Transfers

Transfer of water from agricultural use (irrigation) to municipal use was investigated in the DEIS as the primary water supply that would be developed for the NAA. Similar to this, the current NAA investigation considers ag transfers as the primary water supply component of the NAA. For purposes of the NAA analysis, only the "consumptive use" (CU) portion of native water supplies was assumed as transferrable water per Colorado water law. Any deliveries of C-BT water were deducted from the amount of CU that could be transferred because C-BT water would not be part of a consumptive use transfer (unless specially tied to a ditch share, as is done for the North Poudre Irrigation Company), Transfers of C-BT units are typically transacted separately from the transfer of native CU shares.

The Corps requested the NAA include the general locations of lands for ag transfer. In practice, water sources for the NAA could be obtained from a multitude of different potential sources. The NAA identifies irrigation systems and their associated service areas that are representative of the land requirements for the NAA. However, the Participants could potentially select different irrigation systems than those discussed herein. To aid in identifying feasible and efficient lands as representative of the NAA, a short-list of ditches was developed using the following guidelines:

- Because of the amount of yield that is required from ag transfers to meet the NISP yield requirements, only transfers from larger systems were considered. In practice transfers from smaller ditch systems could occur. The amount of acreage required for ag transfers would vary slightly by ditch.
- Due to logistical, legal, and cost effects of transfers from systems that are located long distances from the Participants, supplies were limited to those that are within the general vicinity of the Participants. This requirement eliminated sources upstream of the Denver metropolitan area, downstream of Greeley, or east of the South Platte drainage in District 2 (i.e., the Beebe Draw area or areas farther east).
- Based on information gathered during Participant interviews, it was determined that transfer of water from irrigated land within Boulder County would be limited due to the patchwork of irrigated land that has been designated by Boulder County and the City of Boulder for open space conservation (see Map 1). Thus, minimal transfers would be possible from irrigated land within Boulder County.

These limitations removed all ditches from the St. Vrain and Boulder Creek basins from consideration. Most of the ditches considered in this analysis were contained in District 3 (Poudre), District 4 (Big Thompson), or District 2 (South Platte between Denver and Greeley). A list of agricultural sources considered for ag transfer is contained in Table 2.



Map 1. Boulder (City and County) Open Space and Irrigated Lands

Table 2. Irrigation Systems Considered for Ag Transfer

Basin	Irrigation System
Poudre Basin	Larimer & Weld Irrigation Company
	New Cache la Poudre Irrigating Company
	Water Supply & Storage Company
	North Poudre Irrigation Company
Big Thompson Basin	Home Supply Ditch
	Greeley-Loveland Irrigation Company
	Consolidated Hillsboro Ditch Company
	Handy Ditch & Reservoir
South Platte Basin	Platte Valley Irrigation
	Lower Latham Ditch
	Fulton Irrigating Ditch
	Farmers Independent Ditch
	Brantner Ditch
	Western Mutual Ditch
	Platteville Irrigating & Milling
	Union Ditch (Dist. 2)
	Lupton Bottom Ditch

Two ditches have current bylaws limiting the transfer of water for municipal use: the Left Hand Ditch Company and the Highland Ditch. The Left Hand Ditch Company bylaws prevent use of water outside of the company's service area (Left Hand Ditch Company 2009). Based on information provided by the Left Hand Water District, the primary rural domestic water provider within the Left Hand Ditch Company service area, the service area of the ditch has little potential for additional municipal water demand. The Highland Ditch Company bylaws could not be obtained for review, but according to the South Platte Decision Support System (SPDSS) Memorandum on the Highland Ditch Company, the bylaws preclude shares from being changed to other uses (LRE 2008b). Because it remains possible that bylaws could be changed given a majority share change in ownership or a potential legal challenge to the bylaws themselves, further analysis was performed to determine whether these sources should be considered for water supplies. For the Left Hand Ditch Company, there is not a substantial amount of water available due to the predominance of City of Boulder and Boulder County Open Space in the ditch service area. For the Highland Ditch Company, it is possible that given a change in bylaws, a substantial portion of the ditch could be transferred. However, there are other ditches in the immediate area, including Handy, Home Supply and Hillsborough, which have transferrable consumptive use water that would not require a change in bylaws. Furthermore, when performing the transferable consumptive use analysis (see Section 3.1.1), the Highland Ditch has the lowest estimated consumptive use of any of these ditches (about 28 percent less than Handy, 40 percent less than Home Supply, and 61 percent less than Hillsborough), which would require the highest amount of agricultural dry-up for transfers. Because of these reasons, Left Hand Ditch and Highland Ditch were not considered in the NAA Options.

2.1.3 C-BT Unit Transfers

Transfer of C-BT units from agricultural to municipal use was a major component of the DEIS NAA. Based on the expanded analysis conducted herein, the DEIS NAA likely overestimated the amount of C-BT units that will be available to fulfill the NISP demand. Analysis conducted by Northern Water estimates that as of 2009 there are about 34,000 C-BT units that could potentially be transferred from agricultural to municipal and industrial (M&I) uses. Transfers are expected to continue at a rate of about 2,000 units per year (Pineda 2009a). Assuming this continued rate of transfer, if the NAA were implemented in 2013, about 26,000 C-BT units would be available for transfer. Assuming a 60 percent quota (the AF of water per C-BT unit) on a firm yield basis (Pineda 2005) this equates to a firm yield of 15,600 AF.

There is expected to be competition for the remaining C-BT units. There are several major non-NISP municipalities that would compete with the Participants for these units. In addition, several NISP Participants have indicated that C-BT units are the primary source of water to be used to fill the portion of future water supply not met by NISP. The 2004 Statewide Water Supply Initiative stated that many water providers plan to obtain additional shares of C-BT units to meet future demands (even with NISP and other on-going water development projects in place), and that "some caution is warranted, in that demand for C-BT water will likely exceed the available supply" (CDM 2004). Therefore, it is reasonable to conclude that in the future, only a minimal amount of agricultural C-BT units would be available to meet the NISP NAA yield requirements.

When developing the potential for future C-BT transfers, it is also important to understand Northern Water policies and restrictions regarding C-BT transfers. In 1995, the Northern Water Board of Directors passed a resolution regarding domestic and municipal C-BT ownership limitations (Northern Water 1995). These rules basically limit the amount of C-BT units that a domestic or municipal water provider can own to the amount of current demand minus the amount of yield that is provided by non-C-BT supplies. Demand is calculated based on the number of taps that the entity has a written commitment to serve. Therefore, "stock-piling" C-BT units to serve anticipate growth that the community is planning for but does not yet have written commitments to serve would be contrary to these rules.

Based on the number of units currently available, anticipated use of these units to serve a portion of un-met demand by NISP Participants, competition from non-NISP Participants, and current rules that discourage "stock-piling" of C-BT units for future growth, it was assumed that a minimal number C-BT units would be available to purchase and transfer for NAA purposes. Although the Participants could potentially meet a small amount of the NISP demand with C-BT, as a conservative assumption, C-BT water is not included as a possible source of supply in the NAA.

2.1.4 Rotational Fallowing / Dry-Year Leases

Rotational fallowing and dry-year leases (or interruptible supply agreements) both involve the transfer of water from specific irrigated lands on a temporary basis rather than a permanent dry-up. For purposes of this document, dry-year leases pertain to agreements that municipal water providers would execute with agricultural entities to make a transfer of CU yield from the agricultural entity during dry years. Rotational fallowing pertains to a concept in which a municipal entity would have an agreement with an agricultural entity or several agricultural entities in which CU yield would be delivered to the municipal entity every year by rotating individual tracts of land that would be fallowed in a given year. The "Alternative Agricultural Water Transfer Methods to Traditional Purchase and Transfer" technical roundtable investigated both of these options as part of Phase II of the Statewide Water Supply Initiative (SWSI) (CDM 2007). This document was consulted as part of the NAA development process.

Dry-year leases were evaluated by both the NISP Phase II analysis and the DEIS. As defined, dry-year leases do not provide a firm yield. Dry-year leases are typically initiated to "firm" an existing yield. That is, a municipal entity's water supply may be adequate during normal or wet years, but may require some additional water during dry years. Because the NISP Participants require 40,000 AF of additional water every year, this type of arrangement is not conducive to meeting the needs of the NISP. In addition, there are several other logistical issues as identified in the SWSI report that make this element unattractive for NISP. Therefore, dry-year leases were not included as part of the NAA.

The concept of rotational fallowing has the potential to provide a consistent water supply through all hydrologic conditions, but it may not be possible in practice on a scale as large as NISP, where 40,000 AF per year are required. As envisioned in the SWSI process (CDM, 2007), agreements with a group of irrigators would be secured in which a particular tract of land is fallowed 1 year out of every 10. Assuming a 40,000 AF firm yield requirement, a CU of 1.1 AF per acre and 1 out of every 10 year rotation, agreements would need to be reached with over 364,000 acres of land. This would be nearly 80 percent of the irrigated lands within the Poudre (District 3), Big Thompson (District 4), and Middle South Platte (District 2) basins, and would be more than 50 percent of the irrigated lands within Northern Water boundaries. Even with an increased frequency of rotation (such as one out of 2 years or 3 years), the amount of land requiring agreement would be a large percentage of those available for such agreement within the area (keeping in mind that many of the irrigated lands in the area already have agreements with other municipal entities for water rights). In addition, as reported in the SWSI document, it is likely that the cost of securing these leases would be more expensive than outright purchase of the same amount of CU water.

The SWSI investigation of rotational fallowing identifies several benefits and drawbacks of rotational fallowing. Some of the major benefits and drawbacks that were identified that differentiate this concept from permanent agricultural dry-up and are pertinent to NISP NAA include (CDM 2007):

- A better or more stable income can be provided to agricultural users since income would be guaranteed during the fallowing year and the firming of agricultural yield will result in a more predictable farm yield during a drought.
- A permanent transfer of agricultural water rights may not be needed, avoiding some of the negative effects of a permanent ag transfer.
- Rotational fallowing could maximize the benefits of a non tributary groundwater conjunctive use program. Non tributary nonrenewable groundwater has a firm annual yield that does not vary from wet to dry years as long as the resource is not depleted.

The life of this groundwater resource could be extended by relying on a rotating agricultural fallowing program in average to above average years and pumping groundwater only during below average years. In these below average years the yield from the rotating fallowing can be used to firm the yield of the agricultural users that are irrigating during those years.

- As for other interruptible supply arrangements the lands involved must remain in irrigation in perpetuity. The agricultural users would need to bind themselves to continue agricultural irrigation use and to fallow the land for a year as required.
- This may be a more expensive approach than a permanent ag transfer. Incentives would need to be substantial to induce an agricultural user to forego the right to sell the water in the future. Annual payments would be required for the agricultural users that are fallowing each year. In addition the transaction costs to assemble and administer a suitable program must be evaluated.
- Some agricultural crops such as orchards, vineyards, and some hay crops are difficult to fallow and may not be appropriate for a rotating fallowing program.
- Agricultural supplies under a rotating program may not be in the needed location or of sufficient quantity. The water from the fallowed lands must be transferred to the municipal & industrial water supply intakes or delivered to the water treatment facilities and may require advanced treatment if the yield is to be used for this purpose. This could require major infrastructure investments in pipelines, pump stations, and advanced treatment facilities.
- Soil, weed, labor, and equipment management issues must be considered for the fallowed lands. A farm operation involves not only the planting irrigating and harvesting of crops but the hiring of labor and maintenance of equipment. In addition the management of soil erosion and weed growth will be issues on irrigated fields that are temporarily dried up.
- Storage would be required to firm the yield for all parties. Municipal and Industrial users would need storage to carry irrigation season water over to the non irrigation months and storage will be needed to firm the agricultural supplies and provide for the replacement of delayed return flows from the fallowed lands.

For purposes of the NISP NAA, rotational fallowing was not explicitly considered simply due to the large quantity of land for which these types of agreements would be required. However, as part of any alternative that contains ag transfers, it is possible that a rotational fallowing concept could be implemented on a much smaller scale to supplement water supplies that are obtained through ag dry-up. The facilities required to deliver this water to the NISP Participants would be as or more extensive than those described for the ag transfers that are part of each NAA option.

2.1.5 Groundwater

Groundwater development was discussed as a potential water supply element in the NISP Alternatives Evaluation Report (HDR 2007). Both alluvial and bedrock aquifers were evaluated as a potential source. In general, alluvial aquifers are currently used to the maximum extent practicable and any new development would require a like amount of augmentation water to replace depletions to surface water resources that are caused by the groundwater pumping. Consequently, there is no net water supply provided by alluvial groundwater pumping alone. Furthermore, the water quality of alluvial groundwater is typically as poor as or poorer than the nearby surface water sources.

Bedrock aquifers are those associated with the Denver Basin aquifers. The Denver Basin aquifer is a source for many municipal entities in the Denver metropolitan area. However, because the bedrock aquifers are non-renewable sources, many of the entities that rely heavily on the bedrock aquifers are currently evaluating renewable sources. Similarly for the NISP Participants, bedrock aquifers would not provide a reliable future water supply.

For these reasons, neither alluvial or bedrock groundwater development were included as a water supply option for the NAA.

2.2 Storage Component

The storage component of the NAA could rely on either or both existing storage sites and new storage sites. Use of existing facilities could include use of a share of an existing facility based on purchases of shares in the irrigation company or district owning the reservoir, or outright purchase of an existing reservoir. New storage facilities could include traditional storage reservoirs, gravel lakes, or aquifer storage and recovery. Each of these is discussed in the following sub-sections.

One consideration in development of the NAA is the tradeoff between the use of several small reservoirs or fewer larger reservoirs for storage. Any NAA developed will likely require storage. Based on the hydrologic analysis conducted in this study, storage requirements could range from 47,000 AF to 120,000 AF (see Section 4). Several aspects must be considered when evaluating whether multiple smaller sites or fewer larger sites would better serve the needs of the Participants, including evaporation losses, location, infrastructure requirements, and ability to develop. Each of these is briefly discussed below:

- **Evaporation** – Smaller storage facilities are typically shallower with larger surface areas per unit storage than larger facilities. This leads to increased evaporation from the smaller facilities, which must be offset by additional water supplies requiring additional ag transfers. Larger, shared storage would be more efficient for the NAA.
- Figure 3 compares total expected evaporation from a single larger facility to configurations of multiple smaller facilities (20,000 AF, 5,000 AF and 2,500 AF) with total storage equal to the single large reservoir. As an example, the figure shows total average annual evaporation for each configuration at an average annual storage of 55,000 AF (simulated average annual storage for the recommended NAA, see Section 5). Average annual evaporation of the configuration containing eleven 5,000 AF reservoirs is nearly 1,700 AF (or about 50 percent) more than the single large reservoir configuration, while the configuration with 22 2,500 AF reservoirs is approximately 2,900 AF (or about 100 percent) more. The analysis assumes that the multiple reservoir configurations are operated so that water is released from only one facility at a time, with all other

reservoirs in the configuration remaining full (a best-case scenario for evaporation losses). It should also be noted that this analysis does not consider seepage losses.

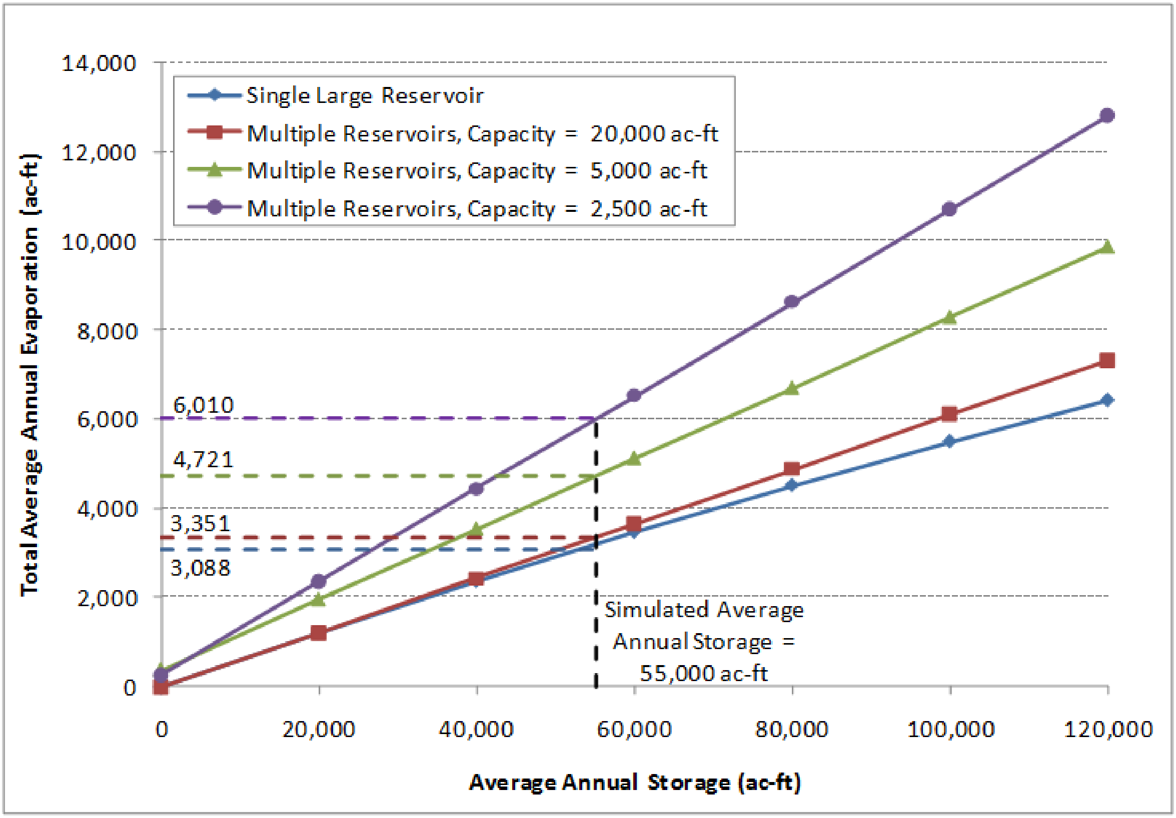


Figure 3. Reservoir Evaporation Analysis

- **Location and Infrastructure** – Location of reservoirs and the infrastructure required to deliver water to and from the reservoirs is a key consideration. Ideal water supplies for the NISP NAA are typically in the upper portions of tributaries where water quality is highest. For reservoir sites that are lower in the basin, including most gravel lakes, infrastructure such as pump stations and pipelines would be needed to deliver this water to the Participants. Unlike many other municipalities that are using gravel pit storage to facilitate exchanges, the NISP Participants do not have adequate exchange rights, nor is there adequate exchange potential during many times of the year and especially drought conditions (see discussion in Section 2.3.2), to deliver NISP water supplies from reservoirs lower in the system to upstream locations. The amount of infrastructure required to deliver water from multiple small reservoirs would likely be extensive and have higher capital and operations and maintenance costs than infrastructure from a single facility.
- **Operational Flexibility** – One key advantage to NISP Participants in having a single or fewer larger reservoirs and common water supplies is the additional flexibility and efficiency that these shared water supplies and infrastructure provide, including the ability to internally trade and lease supplies to other Participants and the decreased operations and maintenance required for a system with fewer facilities. However, one

advantage that multiple smaller sites could provide is the ability to store supplies from multiple sources in multiple locations.

- **Ability to Develop** – In general, smaller facilities would likely be more straightforward to develop than larger facilities. Permitting requirements in general would be less (although for the NISP NAA, it is assumed that reservoirs are sited such that no Corps individual 404 permit or associated NEPA compliance would be required). Additionally, smaller reservoirs would allow the Participants to construct the smaller facilities as needed rather than develop all larger facilities at the outset of the project.

At the options screening state, no storage size restriction was considered. All potential storage options, including large and small existing and new reservoirs and gravel pits, were considered in the sub-sections below. Further discussion on whether smaller or larger storage facilities better meet the needs of the Participants is included in Section 4.

2.2.1 Existing Facilities

The C-BT project contains two major storage facilities on the Eastern Slope (Carter Lake and Horsetooth Reservoir) and one smaller storage facility (Boulder Reservoir). Use of these facilities would likely be on an "if-and-when" basis. In other words, non-C-BT water supplies could only be stored in C-BT facilities when there is storage space available to do so. Because of this arrangement, storage would be considered "non-firm" storage subject to spill. Therefore, C-BT facilities cannot be used for firm supply of non-C-BT water. The Windy Gap Project Participants have encountered these same issues, hence the need for a separate reservoir as is being considered in the Windy Gap Firming Project. In addition, the water quality of proposed NISP NAA water supplies would be considerably worse than existing water quality in C-BT facilities (see section 2.3.1.1). Northern Water and the municipal entities that use C-BT supplies would likely not allow the degradation of C-BT water quality by the NAA water. Therefore, use of C-BT storage facilities by the NISP NAA was eliminated.

It is assumed that pro-rata storage capacity in existing agricultural reservoirs would be made available if CU was transferred from an irrigation system. Evaluation of SPDSS records (LRE 2008b) shows that these reservoirs are drained most years, thus they do not have a carryover storage component. Carryover storage is required by municipalities to ensure reliable water supplies due to variations in climate and hydrology from year to year. Additionally, some of the existing pro-rata storage would likely be required to meet return flow requirements that would be part of a major ag transfer. Storage in existing irrigation reservoirs for annual regulation is considered as part of all preliminary NAA options and final NAA options. However, it is assumed that existing irrigation reservoirs would not have the capability to provide any carryover storage for use by municipalities (i.e. all available capacity in the irrigation reservoirs is required to provide the annual share yield every year). Typically, irrigation reservoirs in the area do not have a significant carryover storage component as they drain and fill each year. In addition, municipal operations of reservoirs result in more storage in the reservoir for the same yield during most times of the year.

In addition to pro-rata storage in existing reservoirs, at least one reservoir, Cobb Lake, may be available for outright purchase. The owner of Cobb Lake was not contacted directly to discuss its availability for purchase. If Cobb Lake could be purchased, then it could be used for carryover storage.

2.2.2 New Reservoirs

The new reservoir storage analysis for the NAA primarily relied on sites evaluated in previous studies. A range of reservoir sites was evaluated for the NISP DEIS alternatives analysis. This list was the starting point for the NAA storage component evaluation. In addition, storage locations investigated for the WGFP EIS (Reclamation 2005), those recently evaluated by the City of Loveland (O'Brien 2009) and those suggested by the NAA team were also considered. This long list of sites was reduced to potential NAA sites based on the following criteria:

- Less than 5 acres of wetlands affected, or more if the wetlands are known to not be jurisdictional (adjacent, neighboring, or have a surface tributary connection to interstate or navigable waters of the U.S.).
- Not located on a waterway.
- Located in the Big Thompson, St. Vrain, or Cache la Poudre basins.
- Was not eliminated from NISP due to being on a waterway, land use issues (such as being located on open space lands), technical issues, or for being an integral component of development plans for other entities.

Table 3 summarizes the sites retained after screening using the criteria listed above. In general, it was difficult to identify potential new storage sites with substantial storage capacity but without wetlands or on a waterway in locations suitable for water delivery to the Participants. However, as described in the previous table, several sites were retained for consideration in the options phase of development. Further screening of the sites and selection of specific sites for inclusion in the NAA options is presented in Section 4.

Table 3. Reservoir Sites Retained for Consideration in the NAA

Name	Basin	Capacity (AF)	Elimination Reason in Previous Studies	Wetlands Affected (acres)
Little Kammerzell Reservoir Rehab	Big Thompson River	10,100		unknown
Thomas Reservoir Rehab	St. Vrain River	10,200		unknown
Wildcat Reservoir Rehab	St. Vrain River	34,800	NISP DEIS: Waterway WGFP DEIS: (60k AF size) noted as intermittent waterway	unknown
Cobb Lake (purchase existing)	Cache la Poudre River	22,300		0
Modified Chimney Hollow Enlargement	Big Thompson River	20,000		2
Hertha Reservoir Enlargement	Big Thompson River	74,300	NISP DEIS: Enlargement to this size inundates downstream homes	1
Ashcroft Draw	Cache la Poudre River	11,500		unknown
Upper Black Hollow Reservoir	Cache la Poudre River	10,700		0
Ashcroft Draw #1	Cache la Poudre River	11,500		unknown
Spring Gulch	St. Vrain River	12,000		4
Rock Creek	St. Vrain River	16,400		unknown
Frederick	St. Vrain River	17,900		unknown
Sixmile Canyon	St. Vrain River	18,000	Boulder County	1
Lykins Gulch	St. Vrain River	20,000	Boulder County	0-4
Broomfield Enlargement	St. Vrain River	219,000	Boulder County	5
Rawhide North	Cache la Poudre River	43,100		1
Glade West	Cache la Poudre River	61,000		unknown
Dry Creek (west of Carter Lake, south of Chimney Hollow)	Big Thompson River	21,000 to 62,300	NISP DEIS: Timeliness - residences impacted	3
Cactus Hill	Cache la Poudre River	104,071		14
Berthoud Hill	Big Thompson River	43,000		NA
Upper Sheep Draw	Big Thompson River	37,000	Apparent waterway	NA

Notes:

(1) Source: Capacity: Corps (2008a) and Reclamation (2005), and Brouwer (2009a), Wetlands: Corps (2008a), Elimination: Reclamation (2005) and HDR (2007).

(2) "unknown" inserted for sites where wetland acreage was not listed by Corps (2008a).

(3) Site visits suggest wetlands are not jurisdictional.

2.2.3 Gravel Pits

Gravel pits were evaluated as potential storage elements, but are not likely to be a major component of the NAA. The DEIS NAA suggested that there was substantial availability of gravel pit storage near most of the Participants. Gravel pits were discussed as a potential storage component with the Participants and the NAA team. It was apparent that there are substantial limitations on the utility of gravel pits for raw water storage in northern Colorado. Gravel pits were eliminated as a concept for the following reasons:

- Since the time when much of the gravel pit research was conducted for NISP, many of the sites have been acquired or developed by municipalities for water storage (Weld County 2010; Larimer County 2010).
- Storage capacity in available northern Colorado gravel pits tends to be in the range of 2,000 to 5,000 AF, generally less than the capacity estimates described in the DEIS. Assuming an average capacity of 3,000 AF, and estimated storage requirements of 47,000 to 120,000 AF (see Section 4) a total of 16 to 40 gravel pits would be needed to meet NISP storage requirements.
- Certain gravel mines may not be excavated soon enough for their full storage capacity to be used for the NAA.
- Some mine operators would only lease storage capacity and would not sell the land to water suppliers (MWH 2009).
- Available gravel pits are typically located in the middle and lower South Platte basin or towards the lower end of the tributaries where water quality is poorer and are located a long distance from existing treatment facilities.
- As previously discussed, evaporative losses would be higher from multiple gravel lakes facilities, requiring more water supply to be acquired; infrastructure requirements would be greater, increasing capital and O&M costs; and the system would result in less operational flexibility for NISP Participants.

Gravel pits may be useful for future storage for some Participants, but due to the issues described above they were not used as a component of the NAA.

2.2.4 Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) is the placing of water into the subsurface for later extraction. ASR was another concept considered by the NAA team and dismissed. The NISP alternatives analysis reviewed the potential for ASR in both bedrock and alluvial aquifers and found that ASR was not a viable component for NISP. Local bedrock aquifers were found to only have the capacity to store several hundred AF per year. Alluvial aquifers were found to have more storage potential but the aquifers were close to the surface resulting in issues with water quality and evaporation (HDR 2007). Finally, with ASR there are questions about how the Participants would maintain control over water stored in a northern Colorado aquifer or aquifers.

2.3 Delivery Component

2.3.1 Existing Facilities

2.3.1.1 C-BT Facilities

C-BT facilities convey water from Carter Lake north to the Poudre River, and south as far as Boulder Creek and the Lower South Platte River. Reclamation owns all C-BT reservoir facilities and the canal systems from Carter Lake to the north while fee title has been transferred to Northern Water for the conveyance systems south of Carter Lake. C-BT facilities could be used in the NISP NAA either by exchange or direct use of the facilities. Water suppliers who are not NISP Participants would probably not accept reduced water quality that would occur due to conveyance of NAA water in C-BT facilities. Initial investigations show that water quality from the NAA water supplies would be considerably worse than the current water quality in C-BT facilities. Therefore, direct use of C-BT facilities is not included in the NAA preliminary options or options.

Use of C-BT facilities by exchange was contemplated in the "Reclamation Contract Subalternative" in the DEIS. In this alternative, the Southern Participants would take delivery of NISP water from Carter Lake by exchange. For alternatives including Glade Reservoir, the exchange would involve with releasing an equivalent amount of replacement water directly to the Poudre River to meet C-BT irrigation needs, directly into the Munroe Canal or delivered by pipeline to Horsetooth Reservoir. For alternatives including Cactus Hill Reservoir, the exchange would involve either conveying releases directly to Horsetooth Reservoir in a pipeline or conveying a portion of the releases in a pipeline to Horsetooth Reservoir and the remaining releases to the Larimer County Canal and the Poudre River. As previously discussed, the water quality of NISP NAA water supplies would be considerably lower than currently in C-BT facilities, including Horsetooth Reservoir. As evidenced by the need to pipe a portion of NISP deliveries directly to Horsetooth Reservoir in the "Reclamation Contract Subalternatives," it is unlikely that there is adequate C-BT demand in the Poudre River and associated irrigation canals to allow exchanging all releases into Horsetooth Reservoir against C-BT releases. Therefore, for the NISP NAA, use of C-BT facilities by exchange is not included in the NAA preliminary options or options.

2.3.1.2 Poudre Valley Canal

The Poudre Valley Canal is an existing canal that diverts water from the Poudre River just upstream of the mouth of the Poudre Canyon and delivers this water to storage reservoirs north and east of Fort Collins. Expanded capacity and improvements to the Poudre Valley Canal are included in all three of the Action Alternatives analyzed in the DEIS. Because the Poudre Valley Canal only conveys storage water to reservoirs (there are some very minimal direct flow rights that are served from the canal), there could be capacity available in the canal during high flow times when all reservoirs are full and during drier times when storage rights are not in priority. Therefore, this canal could be used to convey a junior storage right or exchanged CU water to reservoirs in the Poudre Basin. Because the canal intercepts waters of the U.S., it is questionable regarding whether any improvements to this canal could be made as part of the NAA without an individual permit from the Corps. For purposes of the NAA development, it is assumed that the canal would be used "as-is," and that its current condition and capacity are adequate to convey the amount of water needed for the NAA to storage facilities.

2.3.1.3 Southern Water Supply Pipeline

The Southern Water Supply Pipeline (SWSP) is an existing pipeline system that conveys untreated water from Carter Lake to several Participants in Boulder, southern Weld, and Morgan counties. Participant agreements for the SWSP require that any new water introduced in the pipeline be of similar water quality as that from Carter Lake (Brouwer 2009a). The DEIS assumed that for NISP Participants that also participate in the SWSP, all NISP water would be delivered via the SWSP either by exchange through the C-BT system (Reclamation Contract sub-alternatives), or by a pipeline from either Glade Reservoir or Cactus Hill Reservoir (No Reclamation Contract sub-alternatives). For all of the DEIS alternatives, the water quality delivered to the SWSP is comparable to that currently in the SWSP from Carter Lake.

For the NAA, the SWSP could potentially be used as a conveyance mechanism if the water quality introduced by the NAA would not affect any downstream non-NISP SWSP Participants. Initial investigations show that the NAA options would not have suitable water quality for introduction into the SWSP at locations that would affect a water user not participating in NISP. Pretreatment of the water upstream of the SWSP is generally not a cost-effective option, as described in Section 2.4. The only location that NAA water could be introduced is into the eastern spur, as all SWSP Participants on this spur are also NISP Participants (with the exception of Hudson, which is served by Fort Lupton, a NISP Participant). Therefore, all NAA preliminary options and options assume a separate delivery system for all southern NISP Participants.

2.3.1.4 Pleasant Valley Pipeline

The Pleasant Valley Pipeline (PVP) is an existing pipeline system that conveys water from the North Poudre Supply Canal to the Fort Collins Filter Plant, Greeley's Bellvue Filter Plant, and the Soldier Canyon Filter Plant. For the No Reclamation Contract sub-alternatives, the DEIS assumed that water would be piped from either Glade Reservoir or Cactus Hill Reservoir to the PVP. For all of the DEIS alternatives, the water quality delivered to the PVP is comparable to that currently in the PVP from the North Poudre Supply Canal. As with the SWSP, for the NAA, the PVP could potentially be used as a conveyance mechanism if the water quality introduced by the NAA would not affect non-NISP PVP Participants. However, initial investigations show that the NAA options would not have suitable water quality for introduction into the PVP. Pretreatment of the water upstream of the PVP is generally not a cost-effective option, as described in Section 2.4. If NAA water could be exchanged to the PVP, the water quality would be suitable, but exchange capacity is not reliable enough to depend on.

Thus, it is assumed that NAA water would be delivered to northern NISP Participants through a separate conveyance system.

2.3.2 Exchanges

Exchanges are frequently used in Colorado to "transfer" water from a downstream location to an upstream location. Exchanges can be operated as long as the exchange "does not impair the availability of water lawfully divertable by others and the substituted water is of a quality and continuity to meet the requirements of the purpose for which the senior appropriator has normally been used" (TWF 2004). For instance, the NISP Proposed Action would exchange water from the Larimer & Weld and New Cache irrigation systems to Glade Reservoir by supplying a portion of the service area for these canals from the South Platte Water Conservation Project, then diverting a like amount of water at the Poudre Valley Canal intake to Glade Reservoir.

Any exchange rights developed as part of the NISP NAA would be junior to all other currently decreed water rights, including exchanges and recreational in-channel diversions (water rights for boat or kayak courses). All of the river systems in the study area currently have numerous absolute and conditional water rights decrees that would make the possibility of additional exchanges on the river uncertain. At certain times of the year, it is likely that there would be adequate exchange potential in the rivers to transfer water to upstream locations. However, during drought periods exchange potential would be reduced or non-existent. No modeling has been performed as part of this analysis to quantify future exchange potential. It is assumed for all alternatives that exchanges would not be the primary means to transfer water from downstream to upstream locations, thus infrastructure such as pump stations and pipelines would be required to convey water. However, exchange rights would likely be filed for any of the options and exercised as exchange potential permits in order to maximize water quality and reduce pumping costs. Therefore, the alternate point of diversion (APOD)/exchange operation should be included in the hydrologic analysis of the NAA in the SDEIS.

2.3.3 New Pipelines and Pump Stations

New pipelines and appurtenant facilities represent the most effective way to move water from the locations where water can be diverted to storage, treatment, and delivery locations. Pipelines have the benefit that they can easily transport water with much less regard for topographic constraints than open channels or exchanges, can preserve water quality from the point of diversion to its terminus, and avoid seepage and evaporative losses. Drawbacks to pipelines are that they are costly, and may not have the benefit of taking higher quality upstream water that exchanges can enable.

In general, due to the uncertainty and risk of relying on exchanges, and the topographic and capacity limitations of existing conveyance systems, the NAA will rely heavily on pipelines to transport both raw and finished water. The exceptions are that existing canal systems can divert and deliver CU water to reservoirs, and existing canal systems, such as the Poudre Valley Canal, can deliver water to reservoirs.

2.3.4 Non-Potable Systems / Dual Systems

The possibility of installation of dual water systems (i.e., potable water supply for indoor use and non-potable water supply for outdoor water use) was evaluated for areas of new development in the Participants' service areas.

Retrofit of existing development was not considered in this analysis. Within this report, dual systems differ from traditional non-potable systems in that dual systems imply that non-treated water would be delivered directly to residential lots for irrigation purposes. Traditional non-potable systems typically involve the delivery of raw water or treated water effluent to commercial and large publically owned facilities (i.e. parks and golf courses) for industrial and irrigation uses. There are successful examples of how dual systems have been used for new development in the Northern Front Range, such as the City of Evans (MWH 2009).

It is important to understand in this context that a dual system does not reduce the total new water supply requirements by the Participants. Dual systems would result in same amount of total water deliveries to customers. However, dual systems could expand the location of available water supply, as water delivered through dual systems would not need to meet drinking water standards. Therefore, water supplies that are high in TDS that are difficult to treat for drinking water, such as water from the South Platte and lower portions of the tributaries, could be used in a dual system. Additionally the amount of reverse osmosis that would be required to treat this water to meet drinking water standards could be reduced by not subjecting the non-potable component used in the dual system to this level of treatment (see Section 2.4 for discussion of treatment).

Although dual systems would result in lower treatment costs, these systems would represent an additional capital and operational and maintenance expense for water providers, and would place additional capital costs on developers. The amount of water distribution piping required would be doubled, as all treated water distribution piping that typically occurs in a single pipe distribution system would be need to be paralleled by a non-potable pipe. Additionally, consumers would be faced with additional maintenance requirements due to the use of non-treated water in lawn irrigation systems that are typically designed for treated water applications.

The water dedicated to non-potable uses in these options could be delivered to the Participants in two methods. The first method of delivery would be to pump non-potable water through existing or new alluvial groundwater wells and augment the depletions caused by these wells using NISP water. Typically, augmentation for new wells or those wells that are not currently used would be nearly the same volumetric amount as total pumping through the wells, as any water rights for these wells would be very junior and only in priority for a short amount of time. The second method of delivery would be a pipeline directly out of the reservoir. In this method, some of the water would be "pre-treated" at the water treatment plants to screen particulate matter.

The discussion in the NISP Demand Analysis (Harvey Economics 2006), water master planning documents for the Participants, and information gathered in Participant meetings were used to make an initial determination of whether dual systems for new development could potentially be used to reduce the amount of potable firm yield needed for the NAA. Table 4 summarizes which Participants may feasibly install dual systems in new development to reduce NISP potable water demand. Eaton and Evans appear to have planned on installation of dual systems when they made their NISP firm yield request, so dual use was not considered for their systems.

Table 4. Project Participant New Development Dual Use System Potential

Participant	Dual System Potential and Rationale	NISP NAA Potable Firm Yield (AF)	NISP NAA Non-Potable Firm Yield (AF)
CWCWD	No - mostly rural service area	3,500	0
Firestone	Yes	800	500
Frederick	Yes	1,590	1,010
Dacono	Yes	610	390
Eaton	No - dual use appears to have been considered in NISP request for firm yield (Harvey Economics 2006)	1,300	0
Erie	Yes	3,980	2,520
Evans	No - dual use appears to have been considered in NISP request for firm yield (Harvey Economics 2006)	1,600	0
FCLWD	Yes	1,840	1,160
Ft. Lupton	Yes	1,840	1,160
Ft. Morgan	Yes	2,210	1,390
Lafayette	No - assume that most of water need is not for new neighborhoods, so installation of dual use systems is probably not likely	1,800	0
LHWD	Yes	3,000	1,900
MCQWD	No - mostly rural service area	1,300	0
Severance	Yes	800	500
Windsor	Yes	2,020	1,280
	Total	**28,200**	**11,800**

2.4 Treatment Component

Conventional water treatment is not explicitly part of any of the Action Alternatives or the NAA and is expected to be the responsibility of the Participants. Conventional water treatment of surface waters typically involves coagulation/flocculation, settling, filtration, and disinfection. However, some of the potential water supplies will likely require treatment beyond conventional in order to meet water quality standards and the Participants water quality goals. Water quality challenges for potential NAA source waters are discussed in Appendix B. Treatment components for the NAA include pretreatment and advanced water treatment.

2.4.1 Pretreatment

Most of the Participants rely on water treatment facilities designed to treat water originating in the C-BT system. This raw water is high quality, with minimal water treatment required to meet drinking water standards. In addition, in some cases, water treatment facilities are shared with water providers that are not participating in NISP.

Depending on the diversion point, conveyance facility, storage, and operations, the NAA raw water may not be of a comparable quality to the current raw water sources. In this case, existing water treatment facilities may not be capable of treating the NAA raw water or the Participants may not want to introduce this water to their existing treatment facilities without some pretreatment.

Typical pretreatment upstream of water treatment plants includes settling basins or the introduction of chemicals such as coagulants at surface water pump stations. This type of pretreatment occurs with minimal labor on the part of water suppliers.

Most of the potential NAA water supplies, particularly after storage in reservoirs, would require water pretreatment facilities at least as complex as the Participants' existing water treatment facilities in order to achieve water quality comparable to the existing raw water supplies. Since advanced treatment would be required to meet existing raw water quality levels, the NAA pretreatment facilities would most efficiently produce finished water as well and avoid pumping semi-treated water to existing treatment facilities. Therefore, this concept was eliminated from further consideration.

2.4.2 Advanced Finished Water Treatment

Any finished water treatment beyond conventional water treatment needed to meet water quality standards would be a component of the NAA. There are a variety of treatment technologies that could be implemented in various combinations based on the Participants preferences and the quality of the selected water supplies. Surface water quality in the northern Front Range generally degrades in the downstream direction from the canyon mouths. Any water supplies downstream of the Denver and Fort Collins metropolitan areas would likely require advanced water treatment due to constituents in wastewater effluent and urban runoff.

The City of Aurora's new Water Purification Facility is an example of an advanced water treatment facility that will treat water from the South Platte River downstream of the Denver Metropolitan Area. Aurora's treatment process uses multiple barriers including "natural treatment" via bank filtration and aquifer recharge and recovery, and treatment technologies at their purification facility including precipitative softening, UV advanced oxidation, granular media filtration, and carbon adsorption (Carter et al. 2006). Finally, Aurora's South Platte water supplies are blended with their other mountain water supplies. The natural treatment and the purification technologies will address taste and odor, color, nitrate, pathogen, organic, and micro-pollutant water quality goals. However, TDS can only be treated through RO or by blending with lower TDS waters. Aurora will be able to blend the South Platte water with low-TDS water to achieve their TDS goal of 400 mg/L.

Without a large amount of blending water available for the NISP NAA, the Participants would need to treat high salinity water sources with RO to meet the secondary maximum contaminant level (MCL) of 500 mg/L and the NISP NAA goal of 400 mg/L. Although RO is implemented around the world under various conditions, implementation on a large scale in Colorado is challenging due to brine disposal issues. Typically 15 to 20 percent of the RO feed is rejected as brine while 80 to 85 percent of the feed becomes usable water. Contaminants in the feed water are concentrated in the brine, including TDS, nitrate, and selenium. A large, highly-concentrated brine stream would not be permitted for discharge to surface waters in Colorado.

A thorough presentation of the limitations of brine disposal in Colorado was completed by the Colorado Water Quality Forum Membrane Treatment Workgroup (2007). In addition, two different size RO options were evaluated for the NISP alternatives analysis: 36 MGD (72 MGD peak flow) and 11 MGD (22 MGD peak flow) (Brandhuber 2005 and Brandhuber 2006). The potential brine disposal methods for the brine generated by an NAA RO treatment plant include:

- Treatment at a wastewater treatment facility: Such a facility would need to have enough dilution and treatment capacity to meet its discharge permit limits, particularly for nitrate, and would need to be willing to accept the flow. The largest wastewater treatment facilities in the vicinity of a new regional NAA water treatment plant are Longmont (17 MGD), Greeley (15 MGD), and Loveland (10 MGD) (EPA 2009). These plants are not operated by NISP Participants and would likely require treatment upgrades in order to treat the flow. Therefore, they are not likely brine disposal options.
- High recovery RO combined with deep well injection: Adding additional membrane stages can increase the RO recovery rate to 93 to 97 percent, increasing the volume of water recovered and reducing the liquid brine stream. Deep well injection requires appropriate hydrogeology and a permit for underground injection. There are concerns over the possibility of induced earthquakes due to injection. There may be deep oil and gas wells close enough to a proposed RO facility to be used for disposal, but potential sites were not identified for this analysis.
- High recovery RO combined with zero liquid discharge (ZLD): ZLD typically involves mechanically evaporating the liquid from the brine stream resulting in a solid waste. The generated stream is usually of high enough quality that it can be used as treated water. ZLD is currently used in industrial processes but not for large water treatment facilities (Membrane Treatment Workgroup 2007). The process is very expensive but would not require a surface water discharge. With high recovery RO on a fraction of the NISP firm yield request, the volume of brine generated could be reduced to an amount that could be feasibly evaporated by ZLD.
- High recovery RO combined with evaporation ponds: Evaporation ponds require large amounts of land and the rate of evaporation varies by season. With high recovery RO, it may be feasible to purchase enough land for brine evaporation, avoiding the need for a surface water discharge.

The NISP alternatives analysis found that RO was not feasible. In particular, the analysis concluded that ZLD was not a mature enough technology at the flowrates evaluated (Brandhuber 2005 and Brandhuber 2006). RO could be considered for the NAA at lower flowrates in accordance with current operating ZLD facilities in the United States.

3 Methods of Analysis

The technical analyses performed to evaluate the final NAA options primarily involved a basic water supply/water quality operations model of the option and evaluation of storage sites. A discussion of the methods used to develop the options is contained in the following sections.

3.1 Water Supply Analysis

In order to perform a water supply and operational analysis for the options, a simple Microsoft Excel™ based water supply model was developed. The model was divided into two basic groupings of analysis to fit the options that were developed: a Poudre Basin model and a South Platte Basin model. This allowed the two basins to be modeled as separate systems when necessary.

The following describes the basic model configuration:

- **Basic Data**: time-series CU data, reservoir elevation-area-capacity curves, evaporation data, future monthly demand data (potable and non-potable), time-series or monthly water quality data
- **Inputs**: the amount of acreage associated with ag transfers, the amount of existing and carryover storage included in the analysis, various pipeline and canal capacities, the priority of use for each water supply, and water quality targets
- **Output**: amount of demand met and shortage associated with the option, end-of-month storage contents throughout the simulation, and water quality data throughout the simulation.

The water supply model was run using time-series data from 1950 to 2005. Input variables (see below) were iterated for each option until there were no shortages given the annual 40,000 AF of firm yield delivery requirements.

3.1.1 Consumptive Use Data

Consumptive use estimates were obtained from information being developed as part of the SPDSS. The "Historic Crop Consumptive Use Analysis" report (LRE 2008a) documents the use of irrigated acreage, crop types, monthly climate, data, diversion records, and well information collected as part of the SPDSS in the StateCU CU model to develop monthly full supply and water supply limited CU estimates. Although the report itself only contains summary information, the StateCU input files included with the report were used to generate information for the specific ditches listed in Table 2 that was required for the analysis.

The average annual basin-wide CU estimates for basins within the study area as reported in the SPDSS document (LRE 2008a) are presented Table 5. These estimates are a summary for all ditches within each basin and include all water sources, including supplemental C-BT water supplies and groundwater supplies. Consumptive use estimates for individual ditches can vary greatly from these values based on their particular water rights portfolio, types of crops grown and supplemental water supplies.

Table 5. Average Annual Basin-Wide Consumptive Use Results

Water District	Basin	Acres	Irrigation Water Requirement (AF)	Supply-Limited CU (AF)	Percent Short	Supply-Limited CU (AF/acre)
2	South Platte	172,500	281,773	204,674	27%	1.19
3	Poudre	215,822	328,134	247,906	24%	1.15
4	Big/Little Thompson	77,916	127,156	87,898	31%	1.13
5	St. Vrain Ck	62,927	106,686	60,980	43%	0.97
6	Boulder Ck	51,002	89,294	48,443	46%	0.95
Total		**580,167**	**933,043**	**649,901**	**30%**	**1.12**

Notes:

(1) Source: (LRE 2008)

(2) Supply Limited CU (AF per acre) calculated by MWH as Supply Limited CU (AF) divided by acres.

(3) Study period: 1950-2006

As will be discussed in the following sections, ag transfers are the primary water supply for the options. The operational model developed to analyze the options considers ag transfers from specific ditch systems. These systems were selected due to their larger size, availability of storage, and location within the basin. More information on the specific ditch systems selected for each option is discussed with the specific options. For the Poudre model, the Larimer & Weld, New Cache, and Home Supply (Big Thompson Basin) systems were included as potential water supplies. The North Poudre and Larimer County Canal systems in the Poudre Basin and the Greeley-Loveland system in the Big Thompson Basin have limited potential for municipal waters supply because they already have majority municipal ownership, which may make large additional transfers difficult. For the South Platte model, the Home Supply (Big Thompson Basin), Lupton Bottom, Platteville, Fulton, and Farmers Independent ditch systems were considered for water supply sources.

The CU analysis conducted for the options was very similar to and utilized the same basic data as the analysis conducted at the preliminary option stage. Time-series (1950 to 2006) CU estimates were obtained from StateCU output of the input files used for SPDSS (LRE 2008a). Reductions in CU available from each system were made for the amount of C-BT deliveries that comprised total headgate diversions. Supplemental water supplied by groundwater wells were removed in the CU calculations themselves (CU estimates were for surface water sources only). A summary of the CU analysis for the specific ditches used in the options analysis is presented in Table 6.

Table 6. Consumptive Use Estimates for Options Analysis

Ditch	2006 Acreage	Average Acreage	Total Delivery		C-BT Deliveries		Transferrable (1)	
			Average CU (AF)	Average CU (AF/ac)	Average Div (AF)	Average CU (AF)	Average CU (AF)	Average CU (AF/ac)
Poudre Basin Model								
Larimer & Weld	55,568	63,015	44,234	0.70	29,070	11,104	33,891	0.54
New Cache	32,498	36,444	35,668	0.98	882	461	35,236	0.97
Home Supply	15,819	17,708	16,200	0.91	6,902	3,484	13,090	0.74
Sub-total	103,885	117,166	96,101	0.82	36,853	15,050	82,217	0.70
South Platte Basin Model								
Home Supply	15,819	17,708	16,200	0.91	6,902	3,484	13,090	0.74
Lupton Bottom	3,262	3,865	6,692	1.74	-	-	6,692	1.74
Platteville	3,554	3,877	6,629	1.71	-	-	6,629	1.71
Fulton	7,988	10,287	13,917	1.38	-	-	13,917	1.38
Farmers Independent	6,454	6,783	7,354	1.08	-	-	7,354	1.08
Sub-Total	30,623	35,737	43,437	1.22	6,902	3,484	40,327	0.77
Total	**134,508**	**152,903**	**139,539**	**0.91**	**43,755**	**18,534**	**122,544**	**0.72**

Note:
(1) Transferable CU estimated as total CU minus CU from C-BT deliveries.

3.1.2 Storable Flow Data

In addition to the CU water supplies, diversions from unappropriated storable flow were evaluated for each model. Storable flow was estimated using the results of previous studies and estimates for diversions from existing conditional water rights. Table 7 presents a summary of estimated storable flows within the study area. The following is a summary of the calculation methods for each data set.

- **Poudre** – Storable flows were taken from a dataset developed as part of the Northern Water's analysis of the South Platte Water Conservation Project (Pineda 2009b). The analysis was conducted water years 1970 to 2005. For years prior to 1970, a correlation with flows at the Canyon gage was performed, which resulted in the following equation:

  $$y = 1e^{-6}x^2 - 0.0792x - 17489$$

  where: *y = annual storable flow at canyon mouth*

  x = annual gage flow at canyon mouth

  The regression resulted in an r^2 value of 0.92. Annual storable flows were distributed on a monthly basis based on the average monthly distribution for the 1970 to 2005 period. Reductions in storable flows were made to account for conditional water rights with priorities between the Grey Mountain right and a junior filing, including a total of 900 cfs to account for the Grey Mountain right diversions and Thornton diversions, and 54,416 AF of storage to account for Halligan Reservoir expansion, Seaman Reservoir expansion, and Greeley and Soldier Canyon Filter Plant gravel lakes projects.

- **Big Thompson** – Storable flows were taken from a dataset developed as part of the Phase II analysis of water supply availability in the Big Thompson Basin (Fardal 2003). No adjustments were made for conditional water rights. The dataset study period was 1971-2001. To extend this dataset to fill the 1950 to 2005 study period, a regression with annual natural flow estimates at the Big Thompson at Canyon Mouth gage was developed. This analysis found that for annual natural flow estimates less than 144,000 AF, there would be no unappropriated flows. For natural flow estimates greater than 144,000 AF, annual unappropriated flow was estimated using the equation:

  $$y = 0.8014x - 115591$$

  where: *y = annual unappropriated flow at canyon mouth*

  x = annual natural flow at canyon mouth

  The regression resulted in an r^2 value of 0.53. Although this is not as high as is typically desirable, the relationship was deemed adequate for the level of analysis being conducted herein. The annual unappropriated flow was distributed in May and June based on the ratio of streamflow in occurring in the individual month to the total streamflow in May and June.

- **South Platte** – Storable flows were taken from a dataset recently produced by Northern Water as part of diligence proceedings for the Hardin Reservoir water right (Pineda 2007). These storable flow calculations were based on historical hydrology. Reductions in storable flows were made to account for conditional water rights between the SPWCP water rights and a junior filing. The CDSS water rights database shows that there are over 3,000 cfs of conditional direct flow rights in Districts 1 and 2 (primarily for storage, augmentation, and recharge), and approximately 104,000 AF of storage rights. For purposes of this analysis, it was assumed that conditional direct flow rights would divert up to 1,000 cfs during any given month, but be limited to 104,000 AF per year.

Table 7. Summary of Annual Storable Flow Estimates for NAA Junior Water Right

Year	Annual Storable Flows (AF)		
	Poudre at Poudre Valley Canal Headgate	Big Thompson at Canyon Mouth	South Platte Above Confluence with Big Thompson
1950	0	0	0
1951	0	5,467	0
1952	0	0	0
1953	0	0	0
1954	0	0	0
1955	0	0	0
1956	0	0	0
1957	0	38,454	0
1958	0	0	109,093
1959	0	0	0
1960	0	0	0
1961	0	1,181	0
1962	0	0	53,578
1963	0	0	0
1964	0	0	0
1965	0	17,510	54,211
1966	0	0	26,311
1967	0	0	0
1968	0	0	0
1969	0	5,583	139,876
1970	0	4,082	298,312
1971	0	22,745	77,323
1972	0	0	0
1973	0	7,750	521,457
1974	0	0	24,080
1975	0	0	0
1976	0	0	0
1977	0	0	0
1978	0	0	0
1979	0	3,529	4,051
1980	44,947	102,858	371,011
1981	0	0	0
1982	0	0	0
1983	214,076	54,799	866,022

Year	Annual Storable Flows (AF)		
	Poudre at Poudre Valley Canal Headgate	Big Thompson at Canyon Mouth	South Platte Above Confluence with Big Thompson
1984	0	23,747	659,943
1985	0	0	216,884
1986	0	2,934	88,048
1987	0	0	244,900
1988	0	0	19,000
1989	0	0	0
1990	0	0	0
1991	0	0	0
1992	0	37,605	8,065
1993	0	0	16,969
1994	0	0	0
1995	15,618	0	532,076
1996	0	0	0
1997	0	20,337	165,725
1998	0	13,671	229,140
1999	0	59,293	245,836
2000	0	0	30,119
2001	0	0	0
2002	0	0	0
2003	0	0	0
2004	0	0	0
2005	0	0	0
Average	**4,904**	**7,528**	**89,322**

3.1.3 Water Demands

The operational model requires estimates of monthly demand to ensure that the water supplies being considered are adequate to meet the total annual yield of 40,000 AF per year. summarizes the monthly estimated total demand, as well as potable demand and non-potable demands for NAA Options and Participants that would include dual systems for new development. The monthly demand pattern is based on typical Front Range monthly demand pattern published in the Town of Erie Non-Potable Municipal Water System Master Plan (Erie 2007). This pattern is consistent with historical water use patterns reviewed for LHWD, Lafayette, Fort Lupton, and Firestone. Typically, about 55 percent of total water use is for outdoor water use. Figure 4 and Table 4 (see section 2.3.4) assume that 70 percent of the outdoor water requested for NISP (assumed to be 55 percent of the demand) could be served with non-potable deliveries. As shown, the non-potable part of the dual systems would only be used in the irrigation season.

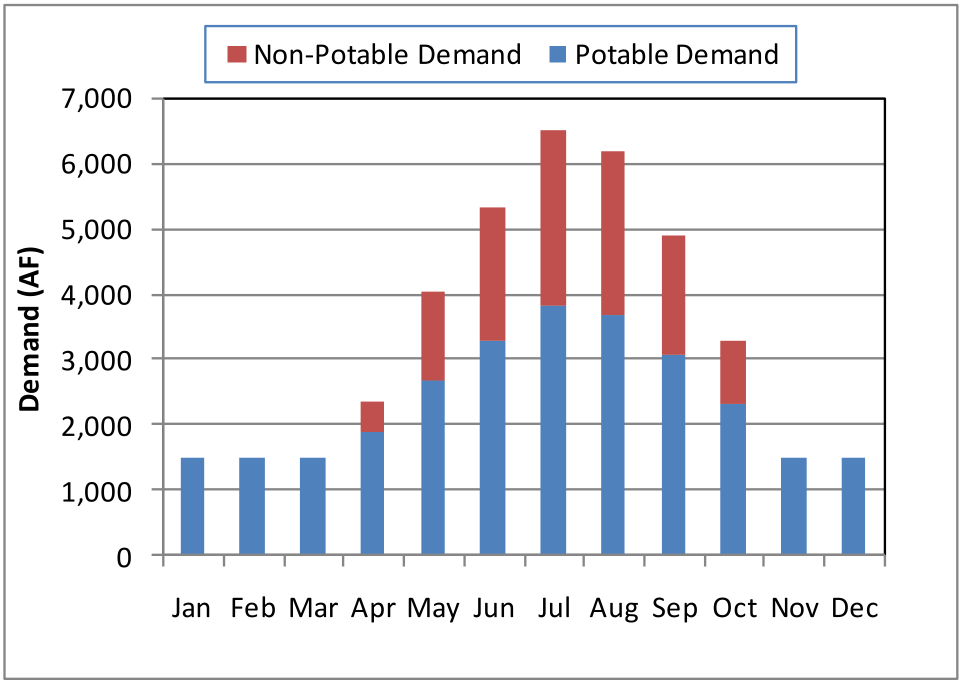


Figure 4. Estimate of Monthly NISP Potable and Non-Potable Demand Considering Dual Systems for New Development

3.2 Salinity Mass Balance

Because of the importance of water quality to the Participants and in the development of options, a mass-balance time-series water quality analysis was built directly into the water supply model. Although there are several water quality constituents that are important to the Participants, the water quality analysis focused on the analysis of TDS. Because the removal of TDS from a water supply stream is difficult through conventional treatment methods, the concentration of TDS in water supplies presents the greatest treatment challenge and has the greatest potential for making a particular water supply source either unusable or very expensive to use.

Where possible, time-series water quality data were used in the analysis. Field and lab water quality data were obtained from the USGS National Water Information System (USGS 2009) and the Big Thompson Watershed Forum (BTWF 2009). These datasets contain results of water samples that were analyzed for several constituents, including specific conductance. A typical conversion factor of 0.67 micrograms per liter (mg/L) of TDS to 1 uS/cm of specific conductance was used for all data (Stevens 2009). This value is very similar to the value of 0.64 for specific conductance less than 5 mS/cm used by Northern Water to make the conversion in its monitoring network (Halley 2009). Time-series TDS data were estimated by first regressing TDS estimated from lab values of specific conductance with streamflow at the time of measurement, then applying this equation to time-series streamflow data measured at the gage. A summary of the regressions is shown in Sources of data: USGS National Water Information System (Poudre and South Platte data); Big Thompson Watershed Forum (Big Thompson data)

Figure 5, while a monthly summary of the time-series data is shown in Table 8.

Table 8. Summary of Time-Series TDS Estimates

Month	TDS (mg/L)			
	Poudre River at Canyon Mouth (Poudre Valley Canal Diversion) (1)	Poudre River at Shields Street (Larimer & Weld Diversion) (1)	Big Thompson at Canyon Mouth (2)	Average South Platte (used for all South Platte Diversions)
Nov	77	235	57	660
Dec	82	232	62	670
Jan	83	220	64	673
Feb	83	207	57	662
Mar	79	166	49	664
Apr	67	124	33	659
May	43	74	28	583
Jun	37	69	31	523
Jul	45	122	37	645
Aug	53	168	42	659
Sep	64	197	46	686
Oct	72	231	53	670
Average	**65**	**171**	**47**	**646**

Notes:
(1) Source of specific conductance data: USGS
(2) Source of specific conductance data: Big Thompson Watershed Forum
(3) Relation of TDS (mg/L) to specific conductance (uS/cm) = 0.67

The regressions resulted in an r^2 values ranging from 0.33 to 0.69. Although the r^2 values are not as high as typically desirable, the equations are in accordance with the relationship observed between streamflow and salinity in Colorado and the equations are considered adequate for the level of analysis being conducted herein.

Northern Water maintains a water quality monitoring network within the Larimer & Weld and New Cache systems. A portion of these data was used for the NAA water quality analysis. Specifically, lab measurements of specific conductance were used to calculate TDS of New Cache canal diversions and releases from existing reservoirs in both systems. Average monthly TDS for New Cache diversions were estimated from specific conductance measurements at station NC2 (canal downstream of Timnath Reservoir). For Larimer & Weld reservoir releases, average monthly values for releases from both Terry Lake (LWRT) and Windsor Reservoir No. 8 (LWR8) were calculated, then averaged together to estimate average monthly TDS for existing reservoir releases. For the New Cache system, average monthly values for Windsor Reservoir releases were used to estimate TDS for existing reservoir releases. A typical conversion factor of 0.67 mg/L of TDS to 1 uS/cm of specific conductance was used for all data. A summary of the resulting datasets is presented in Table 9.

Table 9. Summary of Average Monthly TDS Estimates

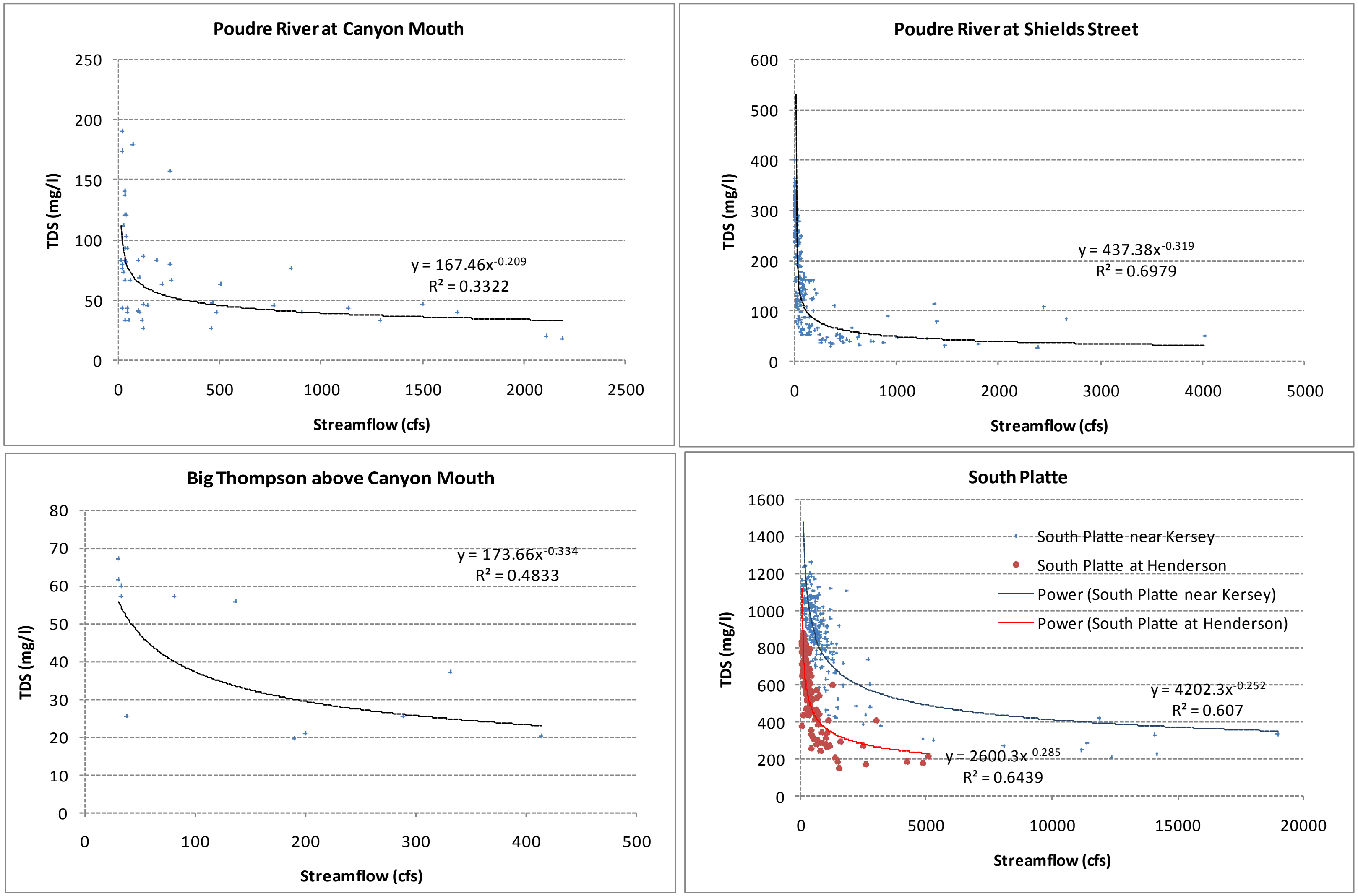
Month	TDS (mg/L)		
	Larimer & Weld - Releases from Existing Reservoir Storage (LWRT, LWR8)	New Cache - Diversions (NC2)	New Cache - Releases from Existing Reservoir Storage (NCRW)
Nov	---	---	---
Dec	---	---	---
Jan	---	---	---
Feb	---	---	---
Mar	---	---	---
Apr	---	---	---
May	384	437	157
Jun	796	274	336
Jul	359	339	404
Aug	312	411	357
Sep	318	436	337
Oct	---	580	---
Average	**423**	**405**	**347**

Notes:
(1) Source of all specific conductance data: Northern Water (station numbers shown in parenthesis).
(2) Relation of TDS (mg/L) to specific conductance (uS/cm) = 0.67
(3) For diversions or releases during months when no data is available, the average is used.

No water quality data was available for releases from Lonetree Reservoir in the Big Thompson basin. For purposes of this study, the TDS of releases from this reservoir was assumed to be the same as overall average of releases from Terry Lake (station LWRT) which was calculated as 340 mg/L.

Saline soils are relatively common in the Front Range. When new reservoirs are initially filled, salts can dissolve out of the soils and increase salinity in the stored water. ERO (2007) sampled the soils, modeled likely salt concentrations (TDS), and performed a sensitivity analysis for the Cactus Hill site. The analysis suggested that initial filling of the reservoir would drive salinity in the water up to about 400 mg/L, but that continued reservoir operation would dilute the salinity of the stored water to reach an equilibrium concentration similar to the inflow concentration after about 8 years. The analysis also showed that salt contributions from watershed runoff were minor.

Based on ERO's (2007) conclusions that the dissolution of salts from soils is only an initial effect, the analysis of salinity in the NAA options does not consider contributions of salts from underlying soils and the watershed when estimating the long-term concentrations of water supplies.



Sources of data: USGS National Water Information System (Poudre and South Platte data); Big Thompson Watershed Forum (Big Thompson data)

Figure 5. Summary of Time-Series Water Quality Data Points and TDS Regression Analyses

3.3 Conveyance Alignments and Sizing

Pipeline alignments were roughly drawn from the water sources to the Participant service area boundaries along existing roads. Optimizing routes and delivering to specific existing infrastructure was generally not considered. Crossings of existing infrastructure, such as state highways, or major drainages that would likely require special crossings such as tunneling were noted. Pipeline lengths and ground elevations were determined in GIS using a digital elevation model. Required pipe sizes were determined from a spreadsheet analysis using the following assumptions about pipeline termination elevations:

- Non-potable systems at ground elevation
- Finished water systems – elevated tank storage tank, 115 feet above ground elevation,
- Water treatment plants – raw water storage at 30 feet above ground elevation.

3.4 Cost Information

MWH developed cost information for ag transfers only. All other cost information discussed in this report was developed by Integra Engineering and GEI (2010).

The cost estimates for ag transfers are comprised of three main components: acquisition of ditch shares, revegetation of lands that are permanently dried as part of the acquisition, and transaction costs, including legal and engineering services. The methods used to develop costs estimates for each of these components is described below and in further detail in Appendix C.

3.4.1 Cost of Ditch Share Acquisition

The cost of ditch share acquisition can vary greatly based on which ditch is involved, the nature of the purchase (whether they are being purchased in one lump sum or over time), economic conditions at the time of purchase, competition from other water users, etc. In order to develop a cost estimate for these shares, several different sources of information were consulted, including reported transactions for the last 10 years of Water Strategist (Stratecon, 2001-2008) on record at Northern Water, current shares for sale from the Colorado Water (Colorado Water, 2009) and discussions experts knowledgeable in this area (Zilas, 2009; Dallam 2009).

3.4.1.1 Revegetation

For the scale of transfer that is being considered for the NAA, it is likely that a large-scale revegetation effort would be required. This is consistent with information presented in the DEIS alternatives analysis, and with large-scale agricultural purchases that have taken place in the both the Poudre Basin (Thornton purchase of Water Supply and Storage Shares) and the Arkansas Basin (Colorado Canal purchase and Rocky Ford Ditch purchase by Aurora).

Revegetation costs were estimated based on general costs of revegetation on mine sites, which are the closest in scale to those required for ag transfer. Based on an analysis of recent mine revegetation costs, a unit cost of $650/acre was used for the NAA options to account for seedbed preparation, seed, seeding, and some additional reseeding and fertilizer.

3.4.1.2 Legal and Engineering Services

Legal and engineering costs for a transfer at the scale being considered would be substantial. A large-scale transfer would garner more attention in water court than a traditional transfer and would be scrutinized substantially. The Thornton transfer of Water Supply and Storage shares represents a typical level of legal and engineering representation that would be required. Based on typical levels of support required for other projects in the region, it is estimated that approximately 5 percent of the total transfer cost would be required for legal and engineering representation during the transfer.

3.4.1.3 Summary

Table 10 presents a summary of ag transfer costs used for this analysis. These values were determined by adding both revegetation costs and a 5 percent markup for legal and engineering services to the market adjusted costs discussed in section 3.4.1.

Table 10. Summary of Estimated Ag Transfer Costs

Area	Range of Ag Transfer Costs (per AF of Municipal Yield)
Poudre Basin	$5,900 - $8,600
Big Thompson Basin	$11,200 - $13,800
Denver Metro Area	$13,800 - $16,400

3.4.2 Cost of Conveyance

Costs of conveyance facilities were estimated by Northern Water based on standard pipe and pump station unit cost curves developed by Integra Engineering and GEI (2010a).

3.4.3 Cost of Water Treatment

Water treatment costs were based on unit water treatment costs from comparable processes and sizes. The cost of conventional water treatment was removed from the total treatment cost for each option because the other NISP alternatives assume water treatment at existing conventional water treatment facilities. The assumptions used to estimate the capital cost of water treatment are summarized below:

- **RO** – unit cost estimated for NISP alternatives analysis 22 MGD capacity option (Brandhuber 2006), $1.40 per gallon per day capacity (does not include pretreatment, assumed equal to conventional treatment which is not included in the NAA analysis)
- **ZLD** – unit cost estimated for NISP alternatives analysis, 22 MGD capacity option (Brandhuber 2006), $5.90 per gallon per day capacity
- **Advanced water treatment** – unit cost of Aurora's Water Purification Facility, 50 MGD capacity (Binney 2008), $1.60 per gallon per day capacity
- **Conventional water treatment** – unit cost estimated from "pretreatment" cost in NISP alternatives analysis, 72 MGD capacity option (Brandhuber 2005), $1.00 per gallon per day capacity (subtracted from advanced water treatment cost)

3.4.4 Cost of Storage

The cost of constructing Cactus Hill was estimated by Integra Engineering and GEI for a capacity of 180,000 AF, larger than considered for the NAA (2010b). The cost per AF was rounded up to $800 per AF for the smaller NAA facility, and $23 million for the road, power line, and pivot relocations was added to the cost, as estimated for the DEIS (Corps 2008a). The cost of acquiring Cobb Lake for the NAA was based on costs of storage included in the DEIS. The unit cost of acquiring Cobb Lake was based on the lower end of all DEIS storage unit costs, or $850 per AF, for a total of $19 million (as shown in Table 11). The cost to construct Berthoud Hill Reservoir was estimated by Northern Water based on a unit cost of $2,000 per AF, or $86 million (Brouwer 2009b).

Table 11. Storage Costs and Estimation of Acquisition Cost of Cobb Lake

Reservoir	Capacity (AF)	Cost per Acre-Foot	Total Cost	Proposed Use
Cactus Hill Reservoir	180,000	$730	$131 million	DEIS Alternatives / NAA Option 3
Glade Reservoir	170,000 – 180,000	$924 – 872	$157 million	DEIS Proposed Action
Galeton Reservoir	40,000	$1,200	$48 million	DEIS Proposed Action
Cobb Lake	22,300	$850	$19 million	NAA Option 1

4 No Action Alternative Options

NAA options are various combinations of feasible concepts for the four components described in Section 2 that meet the 40,000 acre-foot firm yield requirement of NISP. The process for developing the recommended NAA was comprised of three steps, each step with increasing level of detail for the concepts that make up the option (see Figure 6). Each of these steps is described within this section.

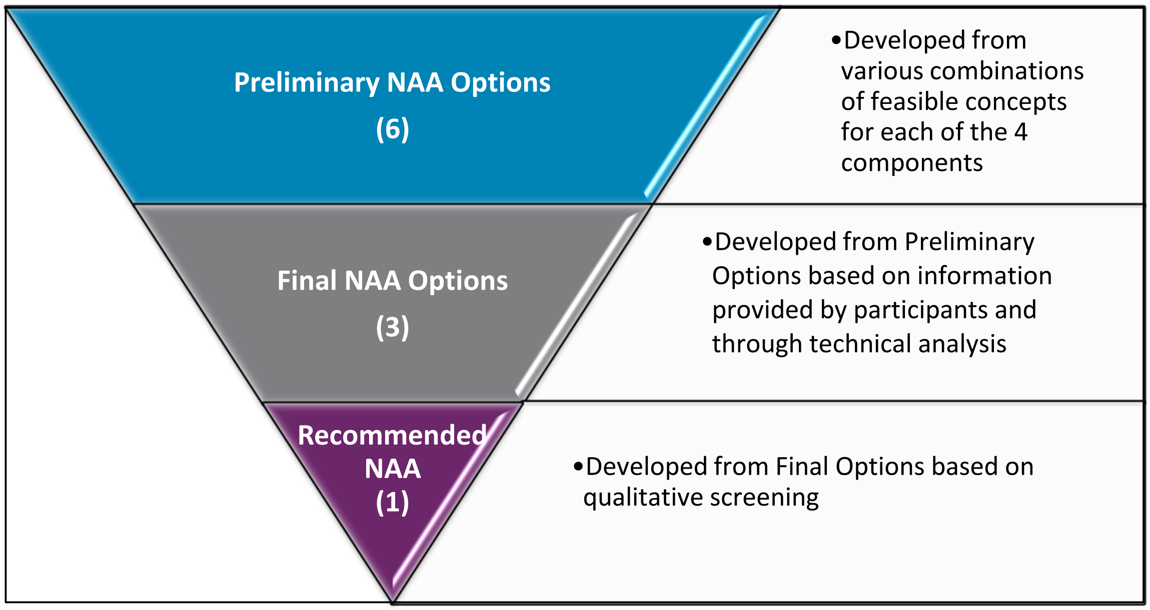


Figure 6. NAA Options Development and Screening Process

4.1 Preliminary NAA Options

The first step in the process was development of preliminary NAA options. Preliminary options were developed from various combinations of the feasible concepts for each of the four components (water supply, storage, conveyance and treatment) that were discussed in Section 2. The options contained general information on the location and sources of potential water supplies, and generalized locations of required storage. Preliminary options were developed by the consulting team prior to meeting with each of the Participants. Fact sheets for the preliminary options were prepared and discussed with the Participants and are included in Appendix A.

4.1.1 Description of Preliminary Options

Three categories of preliminary options were developed.

- **Preliminary Option A: Local Supplies/Local Storage** – Similar to the DEIS NAA, with smaller more localized projects.

- **Preliminary Option B: Northern/Balanced Supplies** – Larger regional project based mostly upon ag transfers from the Poudre and Big Thompson basins.
- **Preliminary Option C: South Platte Natural Pretreatment** – Poudre Basin water supplies for Participants located near the Poudre River, South Platte water supplies for the remaining Participants, and the use of shallow wells to divert, store and pre-treat supplies.

Preliminary Option B was further sub-divided to provide more definition on how the preliminary option could be developed.

- **Preliminary Option B.1: Balance Ag Transfer, Existing Storage** – Implementing enough ag transfer to meet yield requirements without constructing new storage.
- **Preliminary Option B.2: Northern Ag Transfer, Existing Storage, New Plains Reservoir** – Ag transfers in the Poudre and Big Thompson basins with a new reservoir on the plains (east of I-25).
- **Preliminary Option B.3: Northern Ag Transfer, New Foothills Reservoir** – Ag transfers from the Poudre Basin and development of new reservoir in the foothills, likely resulting in the best water quality of the B Preliminary options.
- **Preliminary Option B.4: Balanced Ag Transfer, New Plains Reservoir** – A higher percentage of ag transfers in the Big Thompson Basin with a new reservoir on the plains (east of I-25).

All of the preliminary options involve a substantial amount of ag transfers, including the agricultural water storage rights associated with the transferred ditch company shares.

4.1.2 Discussion of Preliminary Options

Once the preliminary options were developed, they were discussed with Participants in Participant meetings. Participants provided valuable feedback on each of the preliminary options. In some cases, Participants pointed out flaws in some of the components, which meant some preliminary options would need to be modified to be feasible projects. Following the meetings, additional technical analyses were performed to guide development of the options. No formal numerical screening or ranking were performed as part of this analysis. The following is a general summary of these discussions and additional findings regarding the preliminary options:

- Poudre Basin water supplies for the NAA are primarily limited to Larimer & Weld, and New Cache. The North Poudre system is reaching its maximum limit on available municipal water use (Jeavons 2005 and Pineda 2009a), thus large amounts of transfers from the system are likely not available. Based on information from Participants, much of the WSSC water available for transfer to municipal use will probably be used by Participants for water supply in addition to NISP or will be purchased by water providers who are not Participants. In addition, there are already major municipal shareholders in the system that could potentially impede the ability to make large-scale transfers from the system. Therefore, Larimer & Weld and New Cache would be the primary water supplies from the Poudre Basin.

- Acquisition of Cobb Lake is a reasonable concept for providing smaller amounts of storage in the Poudre Basin (up to its capacity of 22,300 AF), and Cactus Hill Reservoir is a reasonable storage concept for providing larger amounts of storage in the Poudre Basin.
- Berthoud Hill Reservoir is a reasonable concept for providing smaller amounts of storage in the southern portion of the study area. No previously identified storage sites met the requirements identified in Section 4 while providing the necessary storage amounts for preliminary option A to be feasible.
- Preliminary option B.3 considered use of a large foothills reservoir to maximize water quality and provide a regional project near the existing SWSP diversion and both the Carter Lake Filter Plant and/or Soldier Canyon Filter Plant. No foothills storage sites were found that met the requirements identified in Section 4. All sites had either jurisdictional wetlands or waters of the U.S. that would require an individual Section 404 permit from the Corps.
- Some smaller gravel pits were identified as potential sites. Although an independent evaluation of gravel pit ownership was not conducted as part of this study, based on discussions with Participants, most existing gravel pits already have agreements with other entities for water storage development. Additionally, some Participants had water quality concerns about using gravel pits, especially those located farther east, as potable water supply reservoirs.
- Use of smaller reservoirs and gravel pit storage was originally contemplated for preliminary option A. However, the small storage sites would be inefficient for both water storage and overall project cost. Furthermore, they would result in more ag dry-up than large storage sites. This directed the NAA process toward the use of larger, shared storage facilities.
- Further analysis of water supplies and water quality in the South Platte showed that it may be feasible under the requirements identified in Section 4 to divert and treat water from the South Platte for use as a potable water supply for the NISP Participants.
- Initial versions of the preliminary options included large ag transfers from Boulder County. Participant feedback and further analysis of available supplies suggested that there is limited opportunity for ag transfers from Boulder County due to the predominance of City of Boulder and Boulder County open space within the county. The preliminary options were changed to reduce ag transfers from Boulder County and this limitation was considered in the development of final options.
- Preliminary option C has several features that made it a less desirable option. First, a year-round water supply is not available to provide augmentation for alluvial groundwater pumping. Consequently, a storage facility would be required to regulate surface water, which defeats one of the main purposes of this type of project. Second, the NISP Participants generally do not have an adequate quantity of water supplies to

provide the amount of blending required to meet water quality targets. Furthermore, the technology used as part of this type of project was considered by some Participants to not be proven technology.

4.2 Final NAA Options

Based on feedback received from Participants and with Northern Water, and subsequent technical analysis, three final NAA options were developed. Information was developed to document the source ditch system and quantity of irrigation dry-up; the potential diversion of native water supplies; specific storage sites and required volume; general alignments and required capacities of pipeline segments; general locations, capacities and description of the type of water treatment required; and the delivery of treated water (and untreated water in Option 1) to the Participants. Table 12 summarizes the components of the final NAA options.

Table 12. Final NAA Options Summary

Component	Option 1 North and South Systems	Option 2 No New Storage	Option 3 Large Plains Reservoir
Associated Preliminary NAA Option	A	B.1	B.2
Water Supply [(1)]	• Ag transfer 44,100 acres • Average yield 41,300 AF • Sources: Poudre, Big Thompson & S. Platte • Junior rights with 4,957 AF average yield	• Ag transfer 91,000 acres • Average yield 64,000 AF • Sources: Poudre & Big Thompson	• Ag transfer 62,000 acres • Average yield 43,900 AF • Sources: Poudre & Big Thompson • Junior rights with 877 AF average yield
Storage	• Shares in existing ag reservoirs • Acquire Cobb Lake 22,300 AF • New Berthoud Hill Reservoir 25,000 AF	Shares in existing ag reservoirs	• Shares in existing ag reservoirs • New Cactus Hill Reservoir 120,000 AF
Conveyance	• Existing canals, existing and new pipelines • North and south systems not connected • Dual use system	• Existing canals, existing and new pipelines • Connected raw water system	• Existing canals, existing and new pipelines • Connected raw water system
Water Treatment	• Advanced water treatment and high recovery RO for 16 percent of supply with ZLD and evaporation ponds for brine disposal • 30 percent of supply untreated for delivery in dual use systems	Advanced water treatment	Advanced water treatment

Note:
[(1)] Average yield of water supplies is diverted water at headgate. Water supplies required are greater than firm yield (40,000 AF) to account for reservoir evaporation and undiverted flow during times when water cannot be delivered or stored.

The following paragraphs generally describe each option.

- **Option 1: North and South Systems** - The Participants generally located near the Poudre River (Evans, Windsor, Fort Collins-Loveland Water District, Severance, and Eaton) would develop northern water supplies and an associated storage facility. The remaining Participants, all located farther south, would develop water supplies from the Lower South Platte Basin and store them in a separate storage reservoir located near the water sources.

  The North System would use ag transfers from the Poudre Basin, existing reservoir storage in agricultural systems, and purchase of the existing Cobb Lake to serve the northern Participants. North System water would be treated at a new regional advanced water treatment plant, but TDS would be low enough the RO would not be required.

  The South System would use ag transfers from the Big Thompson and South Platte basins, existing reservoir storage in the Big Thompson Basin, and a new reservoir east of I-25 near Berthoud to serve the southern Participants. Because the South System would rely on South Platte supplies that generally have high levels of TDS, about 4 MGD of the flow would be treated via high-recovery RO. Brine disposal would be accomplished through a combination of evaporation ponds and ZLD. To reduce the amount of advanced water treatment required, Option 1 also includes a non-potable system that would deliver untreated water to selected Participants for use in dual-use distribution systems to be constructed in new development.

- **Option 2: No New Storage** – The premise of this option is to minimize the need for new storage. Because existing agricultural reservoirs typically do not have much carryover storage (i.e., they are filled and drained annually to meet consumptive use (CU) requirements), enough agricultural CU would be purchased to meet firm yield requirements in the driest year of the planning period.

  Option 2 involves the transfer of water from irrigated land in Larimer & Weld and New Cache systems in the Poudre Basin, and the Home Supply system in the Big Thompson Basin. Transferred water would continue to be diverted from the Poudre and Big Thompson Rivers at the existing diversion locations. Larimer & Weld and New Cache water would be delivered directly to Big Windsor Reservoir. Home Supply water would continue to be delivered to Lonetree Reservoir southwest of Loveland. From these existing reservoirs, water would be delivered to two regional advanced water treatment plants that would serve the northern and southern Participants. RO would not be required.

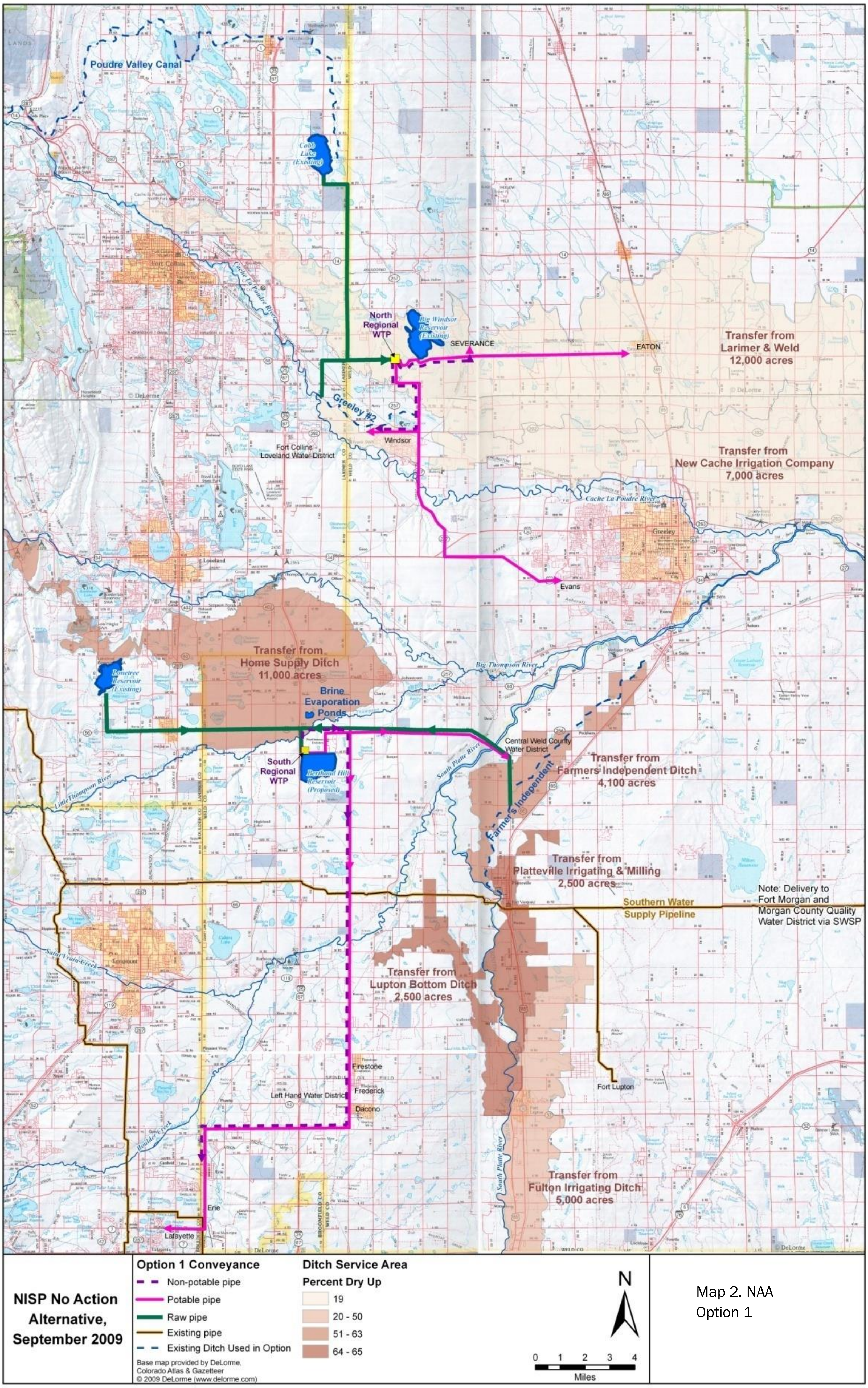
- **Option 3: Large Plains Reservoir** - This option was based on using a large new reservoir and identifying ag transfer supplies based on their ability to be delivered to the reservoir.

  Option 3 involves the transfer of water from irrigated land in Larimer & Weld and New Cache systems in the Poudre Basin, and the Home Supply system in the Big Thompson Basin. As with Option 2, transferred water would continue to be diverted at the existing diversion locations and delivered to Big Windsor Reservoir and Lonetree Reservoir. Cactus Hill Reservoir would be constructed and used for carryover storage, and would be filled from both Big Windsor Reservoir and through the existing Poudre Valley Canal. Water would be delivered to two regional advanced water treatment plants that would serve the northern and southern Participants. RO would not be required.

4.2.1 No Action Alternative Option 1 – North and South Systems

Option 1 consists of two separate projects – the North System would use water supplies and infrastructure in the Poudre Basin to serve the northern Participants, while the South System would use water supplies from the Big Thompson and South Platte basins and infrastructure within these basins to serve the southern Participants. Because the South System relies on South Platte supplies, which generally have high levels of TDS, an RO water treatment plant would be required for some of the water in the South System. To reduce the amount of RO required, Option 1 also includes a non-potable system that would deliver untreated water to selected Participants for use in dual-use distribution systems.

An overview of Option 1 is presented in Map 2. The following subsections provide more details on the water supplies and infrastructure for Option 1.



Map 2. NAA Option 1

4.2.1.1 Option 1 General Description

North System

The North System involves the transfer of water from irrigated land in Larimer & Weld and New Cache systems. Transferred water would continue to be diverted from the Poudre River at the existing diversion locations[1]. Larimer & Weld diversions would flow by gravity in the existing canal system to Big Windsor Reservoir. New Cache water would flow in its existing canal system to a point immediately west of Big Windsor Reservoir. At this location, a pump station and pipeline would be constructed to deliver water directly to Big Windsor Reservoir.

Big Windsor Reservoir would serve as a terminal storage facility for the proposed north water treatment plant. Based on historical operations, Big Windsor Reservoir does not have much carryover storage. Because carryover storage is critical to municipal water supply needs, transferred water that cannot be stored in Big Windsor Reservoir or be immediately treated and delivered would be conveyed to Cobb Lake for carryover storage. A pipeline would be constructed to deliver water from Cobb Lake to Big Windsor Reservoir.

Both treated and untreated (non-potable) water would be delivered from Big Windsor Reservoir and the regional water treatment plant through parallel pipelines. Because both Evans and Eaton already have dual-use systems, no non-potable pipeline would be constructed to serve these entities. The non-potable pipeline would serve Severance, Windsor, and the Fort Collins-Loveland Water District.

South System

The South System involves the transfer of water from irrigated land in the Home Supply system, which is in the Big Thompson Basin, and several smaller ditches located on the South Platte between Brighton and Greeley. Transferred water would be diverted from the existing diversion structure serving the Farmers Independent ditch near Gilcrest. Water would be diverted from the ditch through a pump station and pipeline to a new reservoir located immediately east of I-25 near Berthoud (referred to as Berthoud Hill Reservoir herein). Berthoud Hill Reservoir would serve as both a carryover storage facility and terminal reservoir for a new regional water treatment plant located at the reservoir.

As with the North System, both treated and untreated (non-potable) water would be delivered from Berthoud Hill Reservoir and the regional water treatment plant through parallel pipelines. Water delivered to the Southern Water Supply Pipeline would only be treated water so that Fort Morgan and MCQWD could meet drinking water quality standards using their existing treatment facilities and without any requirements for blending with their existing supplies. Fort Lupton and Fort Morgan would participate in the dual-use system by activating currently inactive wells, then using water in storage for well augmentation purposes. Central Weld and Lafayette would not receive non-potable supplies.

[1] Throughout this section, it is assumed that limited exchange potential exists in all study area streams, thus infrastructure is described and sized accordingly. In actuality, exchanges would be filed where they are appropriate and exercised when exchange potential exists to maximize water quality and reduce pumping costs. See Section 5 for more detail on exchanges for the recommended NAA.

4.2.1.2 Water Supplies – Option 1

Table 13 summarizes the water right transfers and associated existing storage within each system required to meet NISP firm yield delivery requirements to the North and South system Participants. The exact amount of acreage that would be transferred from each ditch may vary based upon transferable CU, storage availability, cost per acre-foot and other factors. For purposes of this analysis, an approximate balance in the percentage of ditch acquired within each grouping was generally sought.

Table 13. Option 1 - Water Rights Transfer Summary

Ditch	Transferable Ditch CU (AF/ac)	Irrigated Land Affected (acres)	Average Yield (AF)	Percent of Ditch	In-Ditch Storage Transferred (AF)
North					
Larimer & Weld	0.54	12,000	6,500	19%	4,425
New Cache	0.97	7,000	6,800	19%	1,955
Sub-total	*0.70*	*19,000*	*13,300*	*16%*	*6,380*
South					
Home Supply	0.74	11,000	8,100	62%	12,218
Lupton Bottom	1.74	2,500	4,300	65%	0
Platteville	1.71	2,500	4,300	64%	0
Fulton	1.38	5,000	6,900	49%	0
Farmers Independent	1.08	4,100	4,400	60%	0
Sub-total	*0.77*	*25,100*	*28,000*	*59%*	*12,218*
Option 1 Total	**0.72**	**44,100**	**41,300**	**26%**	**18,598**

In addition to water rights transfers, both projects would also file junior storage rights in the basins that contain diversions to storage. A summary of the junior water rights yields is provided in Table 14. In the Poudre Basin, a junior water right would only yield a small amount of water during very wet years. This water would be diverted through the existing Poudre Valley Canal to Cobb Lake. For the South System, junior water rights would be filed in both the Big Thompson and South Platte basins. As with the Poudre Basin, the Big Thompson Basin would yield only a small amount of water in very wet years. However, in the South Platte, it is expected that a junior water right would produce yield in about two-thirds of the years simulated.

Table 14. Option 1 - Native Water Rights Yield by Basin

System	Poudre (AF)	Big Thompson (AF)	South Platte (AF)	Total (AF)
North system	432	0	0	432
South system	0	1,228	3,317	4,545
Total	**432**	**1,228**	**3,317**	**4,977**

Total annual water supplies provided by Option 1 are approximately 41,300 AF. The 1,300 AF of water supplies that are in excess of the 40,000 AF required for delivery to the Participants would be consumed as evaporation in the reservoirs.

4.2.1.3 Infrastructure Requirements – Option 1

Option 1 would use both existing and new infrastructure. Existing infrastructure would include existing diversion structures and canal systems, use of existing reservoirs that are a part of each ditch system's infrastructure, and acquisition of Cobb Lake. New infrastructure required for Option 1 include raw water pipelines and pump stations, construction of one new reservoir, construction of two regional water treatment plants, and both treated and untreated water delivery pipelines. A description of this infrastructure is presented below.

<u>Storage</u>

For the North System, water would be stored in existing reservoirs that are part of both the Larimer & Weld and New Cache systems. Regulating and terminal storage would be held in pro-rata ownership in several reservoirs connected to these systems, including the Larimer and Weld high mountain system, the Poudre Valley Canal system, Terry Lake, Timnath Reservoir, and Big Windsor Reservoir. Big Windsor Reservoir would be a key facility in the plan, serving as a terminal storage facility for the regional water treatment plant. As shown in Table 13, the purchase of pro-rata shares in these systems would yield approximately 19,000 AF of storage. It should be noted that some of the space obtained in these reservoirs would likely be required to store and release water to meet return flow requirements that may be part of the water rights transfer.

Carryover water would primarily be stored in Cobb Lake. Cobb Lake is an existing reservoir northeast of Fort Collins in Larimer County. It is located at the end of the Poudre Valley Canal and is operated as part of the Larimer and Weld Irrigation Company System. Due to the location and large losses in the canal upstream of Cobb Lake, the importance of Cobb Lake in system operations is declining (LRE 2005). There are indications that the company would be willing to sell the lake (Brouwer 2009a). Total storage of the lake is 22,300 acre-feet with a maximum surface area of 585 acres (LRE 2007). Cobb Lake would continue to be served by the Poudre Valley Canal system when native water rights are in priority, or when Larimer & Weld or New Cache water rights can be exchanged to the Poudre Valley Canal. As mentioned in the previous section, a pump station and pipeline would be constructed to allow water to be delivered from Cobb Lake to Big Windsor Reservoir

The South System would store water in existing reservoirs that are part of the Home Supply system. This primarily includes Lonetree Reservoir, although there are other reservoirs that are part of the system that could be used for storage. Approximately 12,200 AF of storage would be made available in these systems. The primary use of storage in the Home Supply system would be to regulate Home Supply water rights so that they can be blended with South Platte water to produce lower TDS water for treatment. Home Supply water could be stored in a carryover storage facility if necessary. However, the more likely operation is to introduce Home Supply water immediately upstream of the regional water treatment plant.

Most of the regulating, terminal, and carryover storage required for the South System would be at the new Berthoud Hill Reservoir. This site is located east of Interstate 25 near Berthoud in Weld County. The site has a maximum capacity of about 43,500 AF with a 150-foot maximum depth. Based on the water supply analyses and the higher reliability of South Platte water supplies, approximately 25,000 AF of storage would be required at the site. The site has not been evaluated in any recent NEPA processes. It is on land currently used for dry-land wheat farming.

Conveyance

Cobb Lake is currently and would continue to be filled from the existing Poudre Valley Canal. Based on review of historical records, the maximum inflow from the Poudre Valley Canal to the existing Cobb Lake is approximately 180 cfs. Because no major improvements will be made to the Poudre Valley Canal as part of the NAA, the maximum inflow rate through the existing canal will continue to be 180 cfs.

Raw water would be delivered from Cobb Lake to the North Water Treatment Plant via a 10-mile pipeline. Raw water from the New Cache system would be diverted from the Greeley No. 2 Ditch to the North Water Treatment Plant and Big Windsor Reservoir. Treated water from the North Water Treatment Plant would be delivered directly to Severance and to FCLWD and Windsor via a 17-mile pipeline. Treated water would be delivered to Eaton via a 9-mile pipeline.

Raw water would be delivered from Lonetree Reservoir to Berthoud Hill Reservoir via an 11-mile pipeline and from the Farmers Independent Ditch to Berthoud Hill Reservoir via an 11-mile pipeline. Treated water would be delivered from the South Water Treatment Plant to CWCWD via an 11-mile pipeline and to the SWSP, the Tri-Towns, LHWD, Erie, and Lafayette via a 24-mile pipeline.

Non-potable water would be delivered from Big Windsor Reservoir to FCLWD, Severance, and Windsor via a 5-mile pipeline. Non-potable water would be delivered from Berthoud Hill Reservoir to the Tri-towns, LHWD, and Erie via a 24-mile pipeline.

Advanced Water Treatment

The Larimer and Weld water entering the North System would have water quality similar to that of the Poudre River at Canyon location summarized in Appendix B. The Poudre River quality is similar that currently being treated by the Participants at Carter Lake and Horsetooth Reservoir. Water from New Cache would be diverted from the Poudre River via the Greeley No. 2 canal near Timnath, downstream of several wastewater treatment plants and considerable urban and agricultural development. The New Cache water would make up 44 percent of the water supply for the North System. As shown in Appendix B, the water quality of the Poudre River is highly variable at this location. For example, hardness varies from 36 to 1,200 mg/L with an average of 562 mg/L as $CaCO_3$, an average level considered very hard. Figure 7 shows the monthly average hardness near the Greeley No. 2 canal diversion as an indication of how New Cache water quality would vary seasonally. Diversions into the North System would occur during the irrigation season, when water quality is better. However, levels of hardness and other constituents are still elevated in the late spring and early fall.

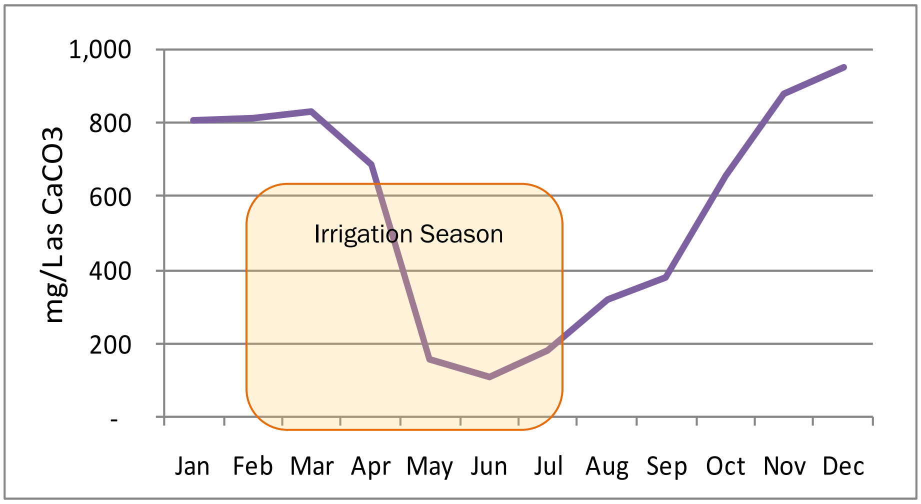


Figure 7. Poudre River near Timnath Seasonal Variation in Hardness

Due to a large portion of the supply coming from New Cache, the Participants may need to implement advanced water treatment to meet water quality standards and would likely want to implement advanced treatment to meet future water quality goals and address public concern regarding source water quality. The mass balance model showed an average TDS for the North System of 377 mg/L, less than the secondary water quality standard of 500 mg/L. As discussed in Appendix B, Aurora and ECCV both have water systems with mountain and South Platte River water sources. These water suppliers have set treated water TDS goals of 400 and 300 mg/L, respectively. In order to supply treated water that is less distinguishable from the Participants' current water supplies, a finished water TDS goal of 400 mg/L was set for NAA treated water. Raw water for the North System would meet this assumed TDS goal with no treatment.

There are a variety of advanced water treatment technologies that could be employed in different combinations to treat the constituents of concern for the North System. For instance, the Participants could construct a conventional plant with the addition of softening and UV advanced oxidation for treatment of taste and odor, color, pathogens, organics, and micropollutants.

South System raw water diverted from the Farmers Independent Ditch would be similar to the South Platte near Henderson location and the Lonetree Reservoir location would be similar to the Big Thompson River below Power Plant location summarized in Appendix B. The Big Thompson source water is comparable to what the Participants are currently treating. However, water from the South Platte River is of lower quality and would require advanced water treatment in order to meet drinking water standards. The average TDS of South System raw water is 503 mg/L, indicating that some portion of the water would need to be treated with RO to meet the assumed TDS goal of 400 mg/L.

The south water treatment plant would include parallel advanced water treatment and RO trains. To achieve the TDS goal, on average 3.8 MGD of the plant flow would be treated through RO. During the month of peak demand, much of the South System water demand would be served from storage and the amount of flow through the RO train would increase to about 15 MGD.

A high recovery RO design would reduce the volume of brine produced, both increasing the amount of treated water produced and reducing the amount of brine requiring disposal. One potential design, based on a case summarized in Mickley (2008)[2], would include the following steps, which are also illustrated in Figure 8:

- First stage RO
- Lime softening (of RO concentrate)
- Second stage RO
- RO concentrate storage pond
- Brine concentrator
- Evaporation pond
- Landfill of solids

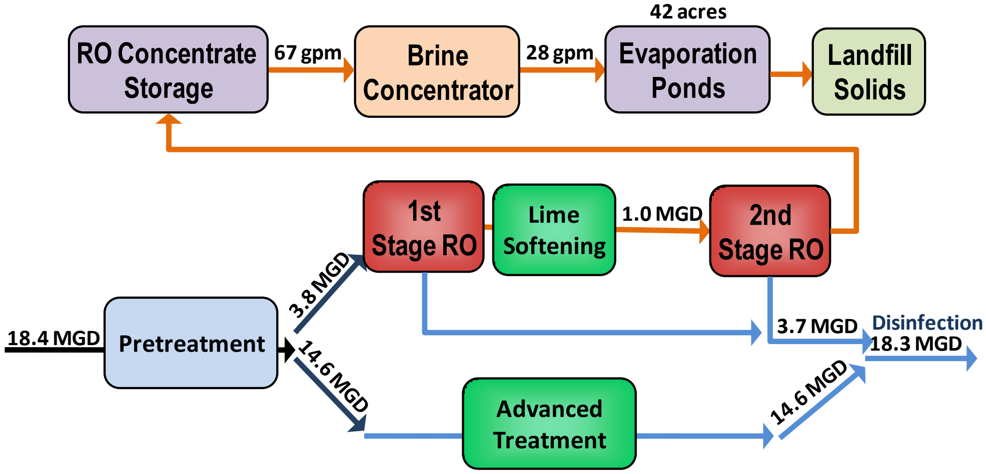


Figure 8. Option 1 – South Water Treatment Plant Schematic (Average Flow)

Figure 8 depicts the south water treatment plant conceptual design with average and peak flowrates through the processes. A combination of evaporation from storage ponds and a brine concentrator could be used so that no liquid discharge would require disposal. On an average basis 67 gpm of brine would require disposal. With a 70 gpm brine concentrator, regulating storage would be required for RO concentrate. Effluent from the brine concentrator would average about 28 gpm, requiring about 42 acres for evaporation ponds. Brine evaporation could be enhanced through the use of air diffusion or heat and air diffusion (CDM 2009).

The actual performance of each of the process steps would vary based upon the chemical composition of the feedwater and environmental conditions. Energy requirements for a brine concentrator are expected to be about 85 kilowatt hours (kWh) per 1,000 gallons of brine flow (Mickley 2008). The average energy usage for the brine concentrator would be about 3 million kilowatt hours per year.

[2] Case 1, Process Scheme 2A

As discussed in the DEIS alternatives analysis, there are concerns about the maturity of ZLD technologies, such as the design described above (Brandhuber 2005 and Brandhuber 2006). Although a municipal RO facility of this size is on a similar scale to other projects currently in the planning and pilot testing stages in Colorado (CDM 2009), the feasibility of implementing an RO project of this size and in this location is by no means certain due to brine disposal challenges. In particular, there are no municipal applications of brine concentrators in the United States. There are several high capacity industrial brine concentrators, including a 700 gallon per minute (gpm) brine concentrator at Tri-State Generation in Craig, Colorado and several smaller concentrators in Colorado (Mickley 2008). If further investigation found that the project could be implemented technically, the capital and operating costs of the project would likely be more expensive than similarly-sized water treatment facilities in operation in Colorado.

There could be environmental concerns about the evaporation ponds and the generated waste solids due to their high concentrations of pollutants. Concentrations of contaminants of concern in evaporation ponds could potentially be high enough that they could be harmful to birds or other species. Therefore, measures would be required to keep wildlife away from the evaporation ponds. A double liner would be required to protect local groundwater from contamination. The generated solids can generally be landfilled as long as the level of radionuclides does not exceed hazardous waste levels. Before implementation of any RO option, the raw water and/or RO concentrate would need to be analyzed to determine if there are any particular contaminants of concern for landfilling.

For the advanced water treatment train at the South Water Treatment Plant, where TDS reduction is not necessary, there are several potential technologies that could be employed to meet water quality standards. One potential design that could be employed includes precipitative softening, UV advanced oxidation, granular media filtration, and carbon adsorption.

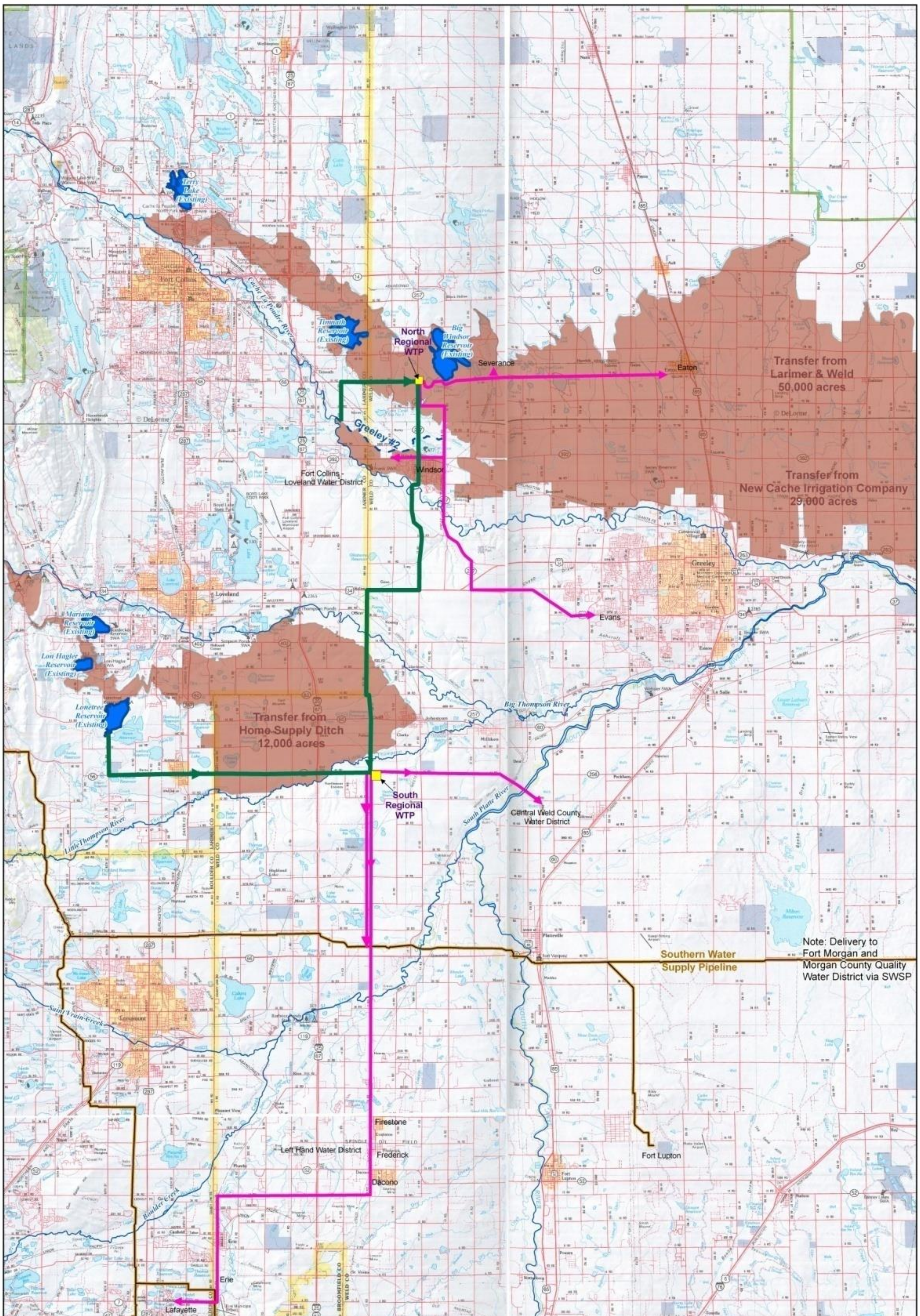
Table 15 summarizes the water treatment plant requirements for Option 1.

Table 15. Option 1 Water Treatment Plant Summary

Segment	Average Month Flow (MGD)	Max Month Flow (MGD)
North Regional Advanced Water Treatment Plant	6.8	11.1
South Regional Water Treatment Plant – Advanced Treatment Train	14.6	14.9
South Regional Water Treatment Plant – RO Train	3.8	14.8
Total	**25.2**	**40.8**

4.2.2 No Action Alternative Option 2 – No New Storage

Option 2 consists of a single project that would deliver water to all NISP Participants without construction of new storage. The option would involve transfer of agricultural water supplies and a pro-rata amount of existing storage in those systems. Because existing storage does not have much carryover storage, enough ag transfers would need to be made so that it fills the firm yield component of water supply deliveries. An overview of Option 2 is presented in Map 3.



Map 3. NAA Option 2

4.2.2.1 Option 2 General Description

Option 2 involves the transfer of water from irrigated land in Larimer & Weld and New Cache systems in the Poudre Basin and the Home Supply system in the Big Thompson Basin. Transferred water would continue to be diverted from the Poudre and Big Thompson rivers at the existing diversion locations. Larimer & Weld diversions would flow by gravity in the existing canal system to Big Windsor Reservoir. New Cache water would flow in its existing canal system to a point immediately west of Big Windsor Reservoir. At this location, a pump station and pipeline would be constructed to deliver water directly to Big Windsor Reservoir. Home Supply water would continue to be delivered to Lonetree Reservoir southwest of Loveland. From there, a pump station and pipeline would be constructed to deliver water to the raw water pipeline to the south treatment facility.

Option 2 would have two regional water treatment plants: northern and southern. Big Windsor Reservoir would serve as a terminal storage facility for both of these facilities, while Lonetree Reservoir would serve as supplemental terminal storage for the southern facility. Having two water treatment plants rather than a single plant allows the Home Supply water to be used more efficiently. Treated water would be delivered from the water treatment plants to the Participants and raw water would be delivered to the Southern Water Supply Pipeline.

4.2.2.2 Water Supplies – Option 2

Table 16 summarizes the water right transfers and associated existing storage within each system required to meet NISP firm yield delivery requirements to all NISP Participants. All transferred water supplies for this alternative are located in the Poudre and Big Thompson basins due to the logistics in conveying transferred water to the treatment and delivery system, and because these basins generally have more existing storage availability than the other systems. Option 2 involves the most ag transfer of the 3 options. As with other options, in determining the amount of acreage transferred from each ditch, a balance in the percentage of ditch acquired within each grouping was generally sought.

Table 16. Option 2 - Water Rights Transfer Summary

Ditch	Transferable Ditch CU (AF/ac)	Irrigated Land Affected (acres) (1)	Average Yield (AF)	Percent of Ditch(1)	In-Ditch Storage Transferred (AF)
Larimer & Weld	0.54	50,000	27,000	79%	18,436
New Cache	0.97	29,000	28,100	80%	8,101
Home Supply	0.74	12,000	8,900	68%	13,328
Total	**0.70**	**91,000**	**64,000**	**78%**	**39,865**

Note:
(1) As part of the refinement of the selected option, additional analysis was performed regarding maximum potential transfer from each ditch. If Option 1 was selected as the recommended NAA, adjustment of transfers and selected ditches may be required to remain within the maximum potential transfer from the selected ditches.

Unlike the other two options, no new storage would be constructed as part of Option 2. Thus, no junior water rights would be filed, and water supplies are limited to those that are available in the ag transfer.

Because of the lack of carryover storage, more agricultural water supplies need to be transferred to obtain the necessary dry-year yields. However, during average and wet years, these transfers would yield more water than could be used by the NISP Participants. Therefore, this water could potentially be leased back to irrigators during these years. On average, nearly 22,000 AF could be made available for lease-back. This water would be available during all years except for the driest years in the model, such as 1954-1955, 1977, and 2002.

4.2.2.3 Infrastructure Requirements – Option 2

Option 2 would use both existing and new infrastructure. Existing infrastructure would include existing diversion structures and canal systems and use of existing reservoirs that are a part of each ditch system's infrastructure. New infrastructure required for Option 2 includes raw water pipelines and pump stations, construction of two regional water treatment plants, and both treated and untreated water delivery pipelines. A description of this infrastructure is presented below.

<u>Storage</u>

As previously discussed, water would be stored in existing reservoirs that are part of the Larimer & Weld, New Cache, and Home Supply systems. Regulating, carryover, and terminal storage would be held in pro-rata ownership in several reservoirs connected to these systems, including the Larimer and Weld high mountain system, the Poudre Valley Canal system, Terry Lake, Timnath Reservoir, Big Windsor Reservoir, Lonetree Reservoir, Mariano Reservoir, and Lon Hagler Reservoir. Big Windsor Reservoir would be a key facility in the plan, serving as a terminal storage facility for the north water treatment plant, and partially serve as terminal storage for the south water treatment plant. Lonetree Reservoir would be the other key reservoir, as it would serve as terminal storage for the south water treatment plant. Reservoirs would be operated in a manner to optimize water quality. This would require rotating releases among reservoirs to prevent evapoconcentration of salts from occurring in any one reservoir. As shown in Table 13, the purchase of pro-rata shares in these systems would yield nearly 40,000 AF of storage. It should be noted that some of the space obtained in these reservoirs would likely be required to store and release water to meet return flow requirements that may be part of the water rights transfer.

<u>Conveyance</u>

Raw water from the New Cache system would be diverted from the Greeley No. 2 Ditch to the North Water Treatment Plant and Big Windsor Reservoir. Raw water would be conveyed from Big Windsor Reservoir and the North Water Treatment Plant to the South Water Treatment Plant in a 17-mile pipeline. Treated water from the North Water Treatment Plant would be delivered to Severance, FCLWD, Windsor, and Evans in a 17-mile pipeline. Treated water would be delivered to Eaton via a 9-mile pipeline.

Treated water from the North Water Treatment Plant would be delivered directly to Severance and to FCLWD and Windsor via a 17-mile pipeline. Treated water would be delivered to Eaton via a 9-mile pipeline.

Raw water would be delivered from Lonetree Reservoir to the South Water Treatment Plant via an 11-mile pipeline, from the Farmers Independent Ditch via a 15-mile pipeline, and from Big Windsor Reservoir via a 21-mile pipeline. Treated water would be delivered to the SWSP via a 5-mile pipeline. Treated water would be delivered from the South Water Treatment Plant to CWCWD via an 11-mile pipeline and to the Tri-Towns, LHWD, Erie, and Lafayette via a 24-mile pipeline.

Advanced Water Treatment

Two regional water treatment plants would be constructed as part of Option 2. The north plant would have an average monthly flow of 12.5 mgd, while the south plant would have an average monthly flow of 23.2 mgd.

Both treatment facilities would rely on water supplies from the Poudre Basin. The average raw water TDS based on the mass balance model is about 333 mg/L, less than the secondary MCL of 500 mg/L and the assumed water quality goal of 400 mg/L. Consequently, the two water treatment plants would not require RO to meet the TDS goal.

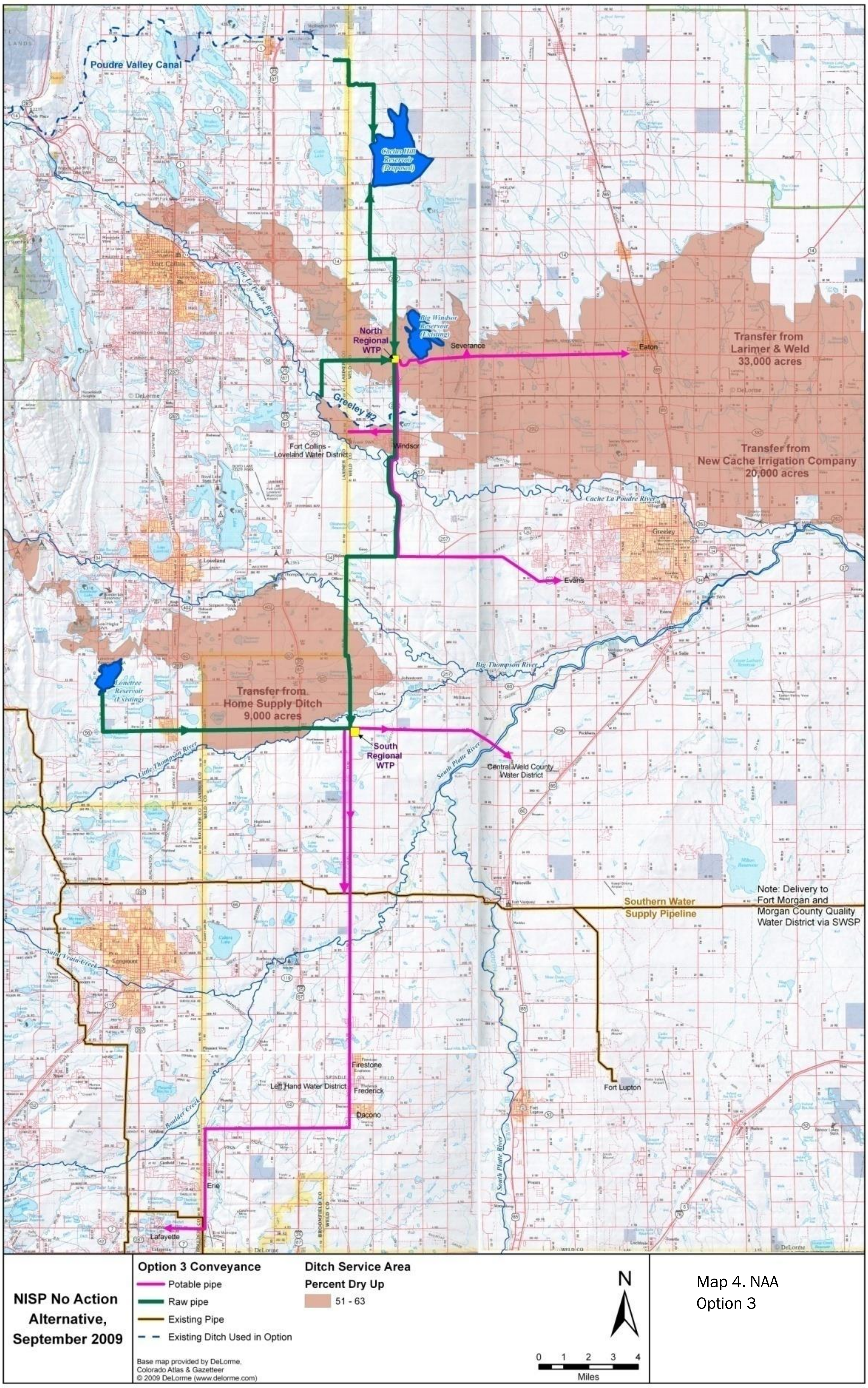
Approximately 44 percent of the water delivered would be from New Cache via the Greeley No. 2 canal, which diverts from the Poudre River near Timnath, downstream of several wastewater treatment plants and considerable urban and agricultural development.

The other water supplies for Option 2, Home Supply and Larimer & Weld, are of higher quality than New Cache. However, the Participants may need to implement advanced water treatment to meet water quality standards and would likely want to implement advanced treatment to meet water quality goals and alleviate public concern due to the New Cache supply. Therefore, both water treatment facilities would include advanced water treatment, but not RO. There are a variety of potential water treatment technologies that could be employed. For instance, the Participants could implement a treatment concept with the following steps:

- Precipitative softening
- UV advanced oxidation
- Granular media filtration, and
- Carbon adsorption

4.2.3 No Action Alternative Option 3 – Large Plains Reservoir

Option 3 consists of single project that would deliver water to all NISP Participants using agricultural water supplies from the Poudre and Big Thompson basins, a pro-rata amount of existing storage in those systems, and a new reservoir at the Cactus Hill Reservoir site. The size of the new reservoir was maximized at its existing site in order to minimize the amount of ag transfers required to meet yield requirements. An overview of the Option is presented in Map 4.



Map 4. NAA Option 3

4.2.3.1 Option 3 General Description

Option 3 involves the transfer of water from irrigated land in Larimer & Weld and New Cache systems in the Poudre Basin and the Home Supply system in the Big Thompson Basin. Transferred water would continue to be diverted from the Poudre and Big Thompson rivers at the existing diversion locations. Larimer & Weld diversions would flow by gravity in the existing canal system to Big Windsor Reservoir. New Cache water would flow in its existing canal system to a point immediately west of Big Windsor Reservoir. At this location, a pump station and pipeline would be constructed to deliver water directly to Big Windsor Reservoir. Home Supply water would continue to be delivered to Lonetree Reservoir southwest of Loveland. From there, a pump station and pipeline would be constructed to deliver water to the south treatment facility. Cactus Hill Reservoir would be constructed for carryover storage, and would be filled from both Big Windsor Reservoir and through the existing Poudre Valley Canal.

Option 3 would have two regional water treatment plants: northern and southern. Big Windsor Reservoir would serve as a terminal storage facility for both of these facilities, while Lonetree Reservoir would serve as supplemental terminal storage for the southern facility. Having two water treatment plants rather than a single plant allows the Home Supply water to be used more efficiently. Treated water would be delivered from the water treatment plants to the Participants or the Southern Water Supply Pipeline.

4.2.3.2 Water Supplies – Option 3

Table 17 summarizes the water right transfers and associated existing storage within each system required to meet NISP firm yield delivery requirements to the North and South system Participants. All transferred water supplies for this option are located in the Poudre and Big Thompson basins due to the logistics in conveying transferred water to the treatment and delivery system. As with the previous options, a balance in the percentage of ditch acquired within each grouping was generally sought.

Table 17. Option 3 - Water Rights Transfer Summary

Ditch	Transferable Ditch CU (AF/ac)	Irrigated Land Affected (acres) [1]	Average Yield (AF)	Percent of Ditch	In-Ditch Storage Transferred (AF)
Larimer & Weld	0.54	33,000	17,800	52%	12,168
New Cache	0.97	20,000	19,400	55%	5,587
Home Supply	0.74	9,000	6,700	51%	9,996
Total	**0.70**	**62,000**	**43,900**	**53%**	**27,751**

Note:

[1] As part of the refinement of the selected option, additional analysis was performed regarding maximum potential transfer from each ditch. As Option 3 was selected as the recommend NAA, adjustments were made to meet maximum estimated maximum potential transfer from the selected ditches. See section 5 for more information.

In addition to water rights transfers, a junior water right would be filed in the Poudre Basin. On average, this water right would yield about 900 AF per year. Even in wet years the junior water right would not yield a large amount of water. This water would be diverted through the existing Poudre Valley Canal to Cactus Hill Reservoir.

Total water supplies for Option 3 are approximately 43,900 AF. The 3,900 AF of water supplies that are in excess of the 40,000 AF required for delivery to the Participants would be consumed as evaporation in the reservoirs, or spilled when the transferred agricultural water is available during times when carryover storage is full or there is inadequate conveyance capacity to the carryover storage reservoir.

4.2.3.3 Infrastructure Requirements – Option 3

Option 3 would utilize both existing and new infrastructure. Existing infrastructure would include existing diversion structures and canal systems and use of existing reservoirs that are a part of each ditch system's infrastructure. New infrastructure required for Option 3 includes a new, large reservoir, raw water pipelines and pump stations, construction of two regional water treatment plants, and both treated and untreated water delivery pipelines. A description of this infrastructure is presented below.

<u>Storage</u>

As previously discussed, water would be stored in existing reservoirs that are part of the Larimer & Weld, New Cache, and Home Supply systems. Regulating, carryover, and terminal storage would be held in pro-rata ownership in several reservoirs connected to these systems, including the Larimer and Weld high mountain system, the Poudre Valley Canal system, Terry Lake, Timnath Reservoir, Big Windsor Reservoir, Lonetree Reservoir, Mariano Reservoir, and Lon Hagler Reservoir. Big Windsor Reservoir would be a key facility in the plan, serving as a terminal storage facility for the north water treatment plant, and partially serve as terminal storage for the south water treatment plant. Lonetree Reservoir would be the other key reservoir, as it would serve as terminal storage for the south water treatment plant. Reservoirs would be operated in a manner to optimize water quality. This would require rotating releases among reservoirs to prevent evapoconcentration of salts from occurring in any one reservoir.

Cactus Hill Reservoir, at 120,000 AF, would be constructed to store water from the Poudre River system. Cactus Hill Reservoir is included as part of Alternatives 3 and 4 in the DEIS and has already received extensive environmental review. It is located between Cobb Lake and Black Hollow Reservoir in the Black Hollow drainage.

<u>Conveyance</u>

The proposed Cactus Hill Reservoir would be filled from both a pipeline from Big Windsor Reservoir and the Poudre Valley Canal. A pipeline from Big Windsor Reservoir is required because there would likely be times when CU water available in the New Cache system could not be exchanged to the Poudre Valley Canal. The pipeline from Big Windsor Reservoir to Cactus Hill Reservoir would be a bi-directional pipeline, which would allow releases from Cactus Hill Reservoir back to Big Windsor Reservoir and the regional water treatment plant. The capacity of the pump station to Cactus Hill Reservoir would be approximately 60 cfs, while the maximum release rate from Cactus Hill Reservoir through the pipeline would be approximately 80 cfs.

The second way that the proposed Cactus Hill Reservoir could be filled is from the existing Poudre Valley Canal. A pump station and pipeline from the Poudre Valley Canal were investigated as part of the options analysis for the DEIS Action Alternatives. However, these alternatives were sized to capture a much larger flow rate from the Poudre River than Option 2. Based on review of historical records, the maximum inflow from the Poudre Valley Canal to the existing Cobb Lake is approximately 180 cfs. This indicates that the maximum existing flow rate in the Poudre Valley Canal at the location where the pump station and pipeline to the proposed Cactus Hill Reservoir is approximately 180 cfs. In order to ensure adequate capacity for filling the reservoir from the canal, the pump station and pipeline from the Poudre Valley Canal to Cactus Hill Reservoir was sized at 200 cfs.

Raw water from the New Cache system would be diverted from the Greeley No. 2 Ditch to the North Water Treatment Plant and Big Windsor Reservoir in a 4-mile pipeline. Raw water would be conveyed from Big Windsor Reservoir and the North Water Treatment Plant to the South Water Treatment Plant in a 21-mile pipeline. Treated water from the North Water Treatment Plant would be delivered to Severance, FCLWD, Windsor, and Evans in a 17-mile pipeline. Treated water would be delivered to Eaton via a 9-mile pipeline.

Raw water would be delivered from Lonetree Reservoir to the South Water Treatment Plant via an 15-mile pipeline. Treated water would be delivered to the SWSP via a 5-mile pipeline. Treated water would be delivered from the South Water Treatment Plant to CWCWD via an 11-mile pipeline and to the Tri-Towns, LHWD, Erie, and Lafayette via a 24-mile pipeline.

<u>Advanced Water Treatment</u>

Option 3 relies on water supplies of a quality similar to that of Option 2. The average raw water TDS from the mass balance is about 340 mg/L, less than the secondary MCL of 500 mg/L and the assumed water quality goal of 400 mg/L. Therefore, the two water treatment plants would not require RO. However, Option 3 would rely on New Cache for about 26 percent of the water supply. Consequently, the Participants would likely construct advanced water treatment facilities similar to those discussed for Option 2. Table 18 summarizes the water treatment plant average and maximum month design flow rates.

Table 18. Option 3 Water Treatment Plant Summary

Segment	Average Month Flow (MGD)	Max Month Flow (MGD)
North Regional Advanced Water Treatment Plant	12.5	24.3
South Regional Advanced Water Treatment Plant	23.2	45.0
Total	**35.7**	**69.3**

4.3 Comparison of Options

A qualitative screening process was used to evaluate the three options and assist Northern Water and the Participants in selection of a recommended NAA. In order to perform this qualitative screening process, a list of decision criteria was developed using the NAA requirements described Section 1.3. All of the alternatives meet the requirements for permitting and delivering 40,000 AF of firm yield. A total of 6 criteria were developed from the remaining three categories of requirements (reliability, water quality and reasonableness), based on comments received from project Participants during meetings. A summary of the criteria and qualitative evaluation are presented in Table 19. The following is general discussion of the criteria and evaluation for each option.

- **System Reliability and Flexibility** – This criterion generally pertains to all of the NAA requirements discussed in Section 1.3.2, in particular firm yield requirements, drought resiliency, and flexibility of operations. All of the Options were configured to meet the same level of firm yield as the NISP Proposed Action, thus all are equal in this area. For drought resiliency, both Options 1 and 3 include a carryover storage facility that can be used to store water for multiple years and supply water during drought conditions. Because Option 2 does not incorporate a carryover storage facility, the drought resiliency of this alternative is far inferior to the other two options. For flexibility of operations, Option 1 does not include an interconnecting pipeline between the north and south systems, thus trading of water supplies and multiple source locations are not possible, especially for the south system. Option 2 has lower flexibility in operations due to a lack of dedicated storage.
- **Water Quality** – The water quality criterion pertains directly to the water quality issues described in Section 1.3.3. Option 1 has the poorest water quality of the options due to its high reliance on South Platte water supplies. As previously discussed, the southern treatment plant would require an RO train to treat raw water supplies to drinking water standards. Options 2 and 3 have better water quality than Option 1, but still would require advanced water treatment and are still poorer quality than would be delivered by the Proposed Action.
- **Effect on Irrigated Agriculture** – This criterion was developed based on comments by the Participants and based on the general goal of NISP to reduce effects on irrigated agriculture. Even without NISP, based on comments received during meeting, the Participants remain committed to reducing effects of water supply development on irrigated agriculture. The analysis was based strictly on the estimated acreage of dry-up required by the Option. Option 1 results in the fewest acres of dry-up, while Option 2 results in the highest acreage of dry-up.
- **Construction and Water Cost** – This criterion pertains to the reasonableness requirements discussed in Section 1. All of the Participants are interested in obtaining water supplies for the lowest cost alternative that meets the other quantitative and qualitative criteria. Because of the uncertainty involved at this level of estimating for certain components of the options, cost estimates were not developed for each of the options. It is likely that the potential costs for the three options fall within a similar range, and there is not a clear preference of one option over another based solely on cost.
- **O&M Cost** – This criterion also pertains to the reasonableness requirements. No specific O&M costs were developed as part of this analysis. However, based on professional experience with these types of projects, it is likely that Option 1 will have O&M costs that are greater than the other two options, due to the high energy requirements of the RO process, brine disposal for the RO process and the operation of dual systems. All of the options would likely have higher O&M costs than existing water supply projects for the Participants due to the long pipelines and pumping required to deliver water and the need to operate advanced water treatment facilities.

- **Implementation Uncertainty** – This criterion addresses a portion of the reliability requirements described in section 1.3.2. As discussed in that section, the NAA should utilize elements that are proven to be successful along the Front Range of Colorado. Although the RO facilities described for Option 1 have been implemented in this approximate range in Colorado, there remain obstacles regarding their success, particularly in relation to brine disposal. Due to the uncertain terms of current regulations and requirements, it is possible that RO at the scale required for the NAA could be either infeasible or very expensive and energy intensive in the future.

  For Option 2, the amount of ag transfer being considered may exceed the amount of transfer available in the future. Although less than 100 percent of the two remaining large systems in the Poudre Basin is considered, as discussed in previous sections, not all of these systems would be available because not all current shareholders would be willing to sell, and because other entities would compete for this water. If Option 2 were implemented, water supplies would need to be more heavily balanced towards Poudre Basin supplies or shifted to other Big Thompson supplies because the quantity of water considered exceeds the amount that is likely available from this system. Although the amount of water considered for Option 2 would be available through a combination of sources that may include some ditch systems in addition to those specifically mentioned, the amount of transfer required would be very difficult and uncertain to implement.

Table 19. Relative Comparison of Options

Criteria	Option 1 North and South Systems	Option 2 No New Storage	Option 3 Large Plains Reservoir
System Reliability & Flexibility	Low operational flexibility due to unconnected systems	• Lack of carryover storage • Low operational flexibility due to lack of storage	
Water Quality	• South system raw water TDS greater than water quality standard • Lack of maturity of ZLD process	Raw water quality poorer than Carter Lake	Raw water quality poorer than Carter Lake
Effect on Irrigated Agriculture	44,100 acres retired	91,000 acres retired	62,000 acres retired
Construction & Water Cost	Estimated to be within comparable range for all options.		
O&M Cost	• Operation of dual-use systems • Extra cost and energy requirements for RO & brine disposal		
Implementation Uncertainty	Uncertainty in future regulations and environmental concerns for brine disposal	• High percentage of ag transfers from individual ditch companies may be unattainable • Cost estimate uncertainty due to high reliance on ag water purchases	

Note:

(1) Shading indicates where information clearly differentiates a preference of one option over another. Green – higher preference, Pink – lower preference.

4.4 Selection of Recommended NAA

The evaluation and screening of NAA options was reviewed with the Participants and Northern Water. The following is brief discussion of each option.

- **Option 1 – North and South Systems**: This option evolved from Option A in the preliminary options analysis, which was a more "localized" option somewhat similar to the No Action Alternative in the DEIS. Because of limited water supplies near many of the Participants, and challenges with numerous smaller storage facilities such as gravel pits and small new reservoirs, the option became a "North System and South System" option involving two smaller reservoirs, and water supplies from the Poudre Basin to the South Platte Basin.

  Due to water quality issues in the South Platte Basin, RO facilities would be required for the South System. The certainty to which an RO system could be developed at the treatments rates required in Colorado is questionable, primarily due to brine disposal issues and high energy costs. Implementation of dual-use systems in certain Participant communities without existing dual use systems was included to reduce the amount of RO treatment required. Additionally, due to lack of interconnection between the two systems, the combined system provides less water supply and operational flexibility for the NISP Participants as a whole. This option would have the least amount of effects on irrigated agriculture due to the use of South Platte water supplies. However, the tradeoff is reduced water quality requiring RO treatment.

- **Option 2 – No New Storage:** This option, which originally was termed Option B.1 in the preliminary options analysis, was developed as an option that would not require construction of new storage facilities, and utilize storage in existing agricultural storage facilities to the maximum extent possible. Because agricultural storage systems along the Front Range have typically been developed as seasonal storage facilities without much carryover storage, storage in these facilities does not provide the level of drought protection required for municipal water supplies. Similarly, because less storage is available, this option would have the greatest impact on irrigated agriculture because municipal entities would have to continue to rely primarily on transferred direct flow yield during dry years (which is typically much lower than average or wet year yield) rather than relying on carryover storage during dry years. Due to a lack of storage, this option would not be able to take advantage of new junior water rights that could divert currently unappropriated water.

  Staged construction and implementation of this option would likely be easier than other options due to fewer required infrastructure requirements at the outset. However, there could also be issues in conversion of existing storage facilities from an agricultural water supply, which primarily has a defined release to augment late season irrigation requirements, to a municipal water supply that requires releases throughout the year and a desired carryover storage component.

- **Option 3 – Large Plains Reservoir**: This option, which originally was termed Option B.2 in the preliminary options analysis, was developed as a regional solution, and involves the construction of a single larger plains reservoir that could be developed without Corps action, and a mid-level amount of ag transfers. The option would provide the maximum amount of flexibility to the Participants due to a reasonable amount of carryover storage, interconnection amongst all Participants, and proven technologies (i.e. it would not require large-scale RO treatment).

Implementation of any of the final NAA options requires a continued regional partnership between the NISP Participants. More independent NAA options could be possible, but they would result in greater effects to irrigated agriculture. During Participant meetings, all Participants expressed continued interest in a regional project. As part of the NISP process, the Participants have developed the organizational structure and planned implementation strategies that could be adapted directly to this regional solution.

In general, the Participants were concerned about the quantity of agricultural dry-up for all options, the uncertainties surrounding the development of Options 1 and 2 regarding the availability of water supplies and implementation of RO, and the overall cost of implementing any of the options. Ultimately, using the information presented in Table 19, it was determined that Option 3 represents the most likely future action by the Participants if the NISP Proposed Action could not be permitted.

5 Recommended No Action Alternative

This section describes the recommended NISP NAA. As discussed in the previous section, the recommended NAA is based on NAA Option 3, thus much of the information provided in this section is identical to that provided in the previous section describing Option 3. However, some adjustments were made to the option based on supplemental analyses and comments by Northern Water and the Participants. The level of detail provided in this section is intended to provide adequate information for evaluation of effects by the Corps in the SDEIS.

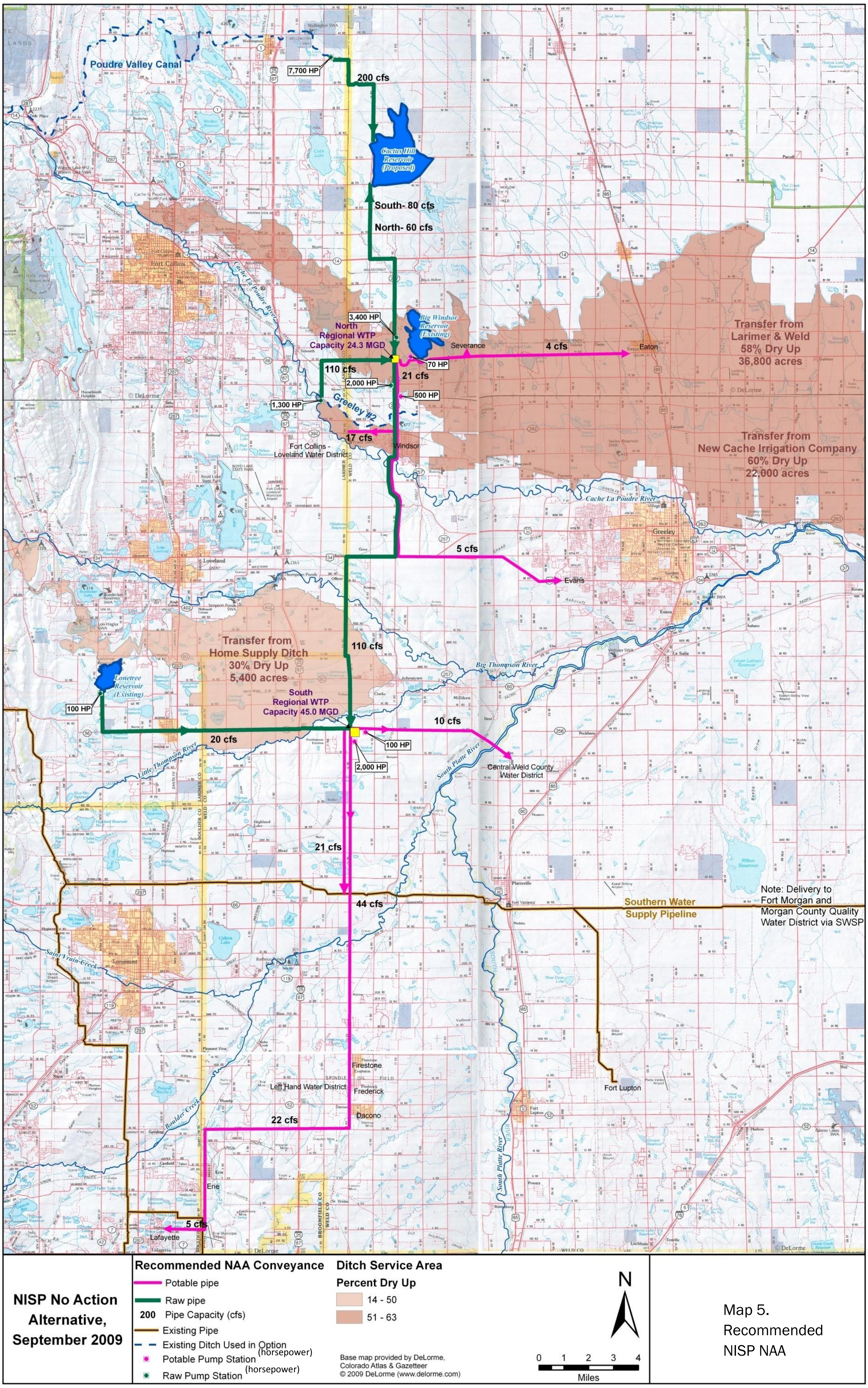
5.1 Adjustments Made to Option 3 for Recommended NAA

Based on supplemental analysis and review, minor adjustments were made to the components and layouts of Option 3. These adjustments are primarily due to changes in the water supply makeup of the alternative. Additional information was obtained on the availability of water from specific ditches that comprise the water supply for Option 3 and estimates on the maximum amount of water that could ultimately be transferred from ditches (see Appendix C for discussion). The following refinements were made when developing the recommended NAA.

- The original Option 3 considered the transfer of approximately 51 percent of the Home Supply system. Based on discussions with sources knowledgeable with this particular ditch system (Zilas 2009) and information obtained in recent water right decrees (Johnstown decree), it was determined that the Town of Johnstown currently owns approximately one-third of the shares in Home Supply. Assuming that 15 percent of this ditch will remain permanently in agriculture, and that Johnstown will continue to purchase some additional shares in the near future, the maximum amount of water available for the NISP NAA was assumed to be 30 percent.
- Due to the changes in the number of shares available from Home Supply, the number of shares purchased in Larimer & Weld and New Cache were increased. Currently, very few shares in either of these systems are owned by municipal interests. As previously discussed, investigation of other systems shows that at least 15 percent of the shares will likely remain in agriculture. Additionally, these ditches will likely become the target of transfers by non-NISP Participants. Assuming that 15 to 20 percent of the shares will be purchased by others, a maximum of 65 percent of these ditches could be transferred by the NISP NAA.

5.2 Description of Recommended NAA

The recommended NAA would deliver water to the NISP Participants using agricultural water supplies from the Poudre and Big Thompson basins, a pro-rata amount of existing storage in those systems, and a new reservoir at the Cactus Hill Reservoir site. The size of the new reservoir was maximized at the site considered in the DEIS in order to minimize the amount of ag transfers required to meet yield requirements. An overview of the Option is presented in Map 5.



Map 5. Recommended NISP NAA

MWH

5.2.1.1 General Description

The recommended NAA would transfer water from irrigated land in the Larimer & Weld, New Cache and Home Supply irrigation systems to municipal use by the NISP Participants. Transferred water would include the historical consumptive use portion of these water rights only. Historical return flow patterns would need to be maintained to prevent injury to senior water rights. Transfers would include pro-rata storage in existing reservoirs associated with these systems. In addition, a new reservoir would be constructed for carryover storage.

For the Home Supply system, transferred water would continue to be diverted from the Big Thompson River at its existing diversion location. Home Supply water would continue to be delivered to Lonetree Reservoir southwest of Loveland. From there, a pump station and pipeline would be constructed to deliver water to a southern treatment facility.

For the Larimer & Weld and New Cache systems, water would be diverted from the Poudre River either at existing diversion locations or at the Poudre Valley Canal diversion location at the mouth of the Poudre Canyon. When diverted at its existing diversion location, Larimer & Weld diversions would flow by gravity in the existing canal system to Big Windsor Reservoir. New Cache water would flow in its existing canal system to a point immediately west of Big Windsor Reservoir. At this location, a pump station and pipeline would be constructed to deliver water directly to Big Windsor Reservoir. When diverted through the Poudre Valley Canal, the Larimer & Weld and New Cache water would be delivered through the existing canal to the proposed Cactus Hill Reservoir just east of the existing Cobb Lake Reservoir. Cactus Hill Reservoir would be constructed for carryover storage, and would be filled from both the existing Poudre Valley Canal and through a new pipeline from Big Windsor Reservoir.

The selected NAA would have two regional water treatment plants: northern and southern. The northern water treatment plant would serve Poudre Basin Participants and Evans (approximately 26 percent of the total demand), while the southern water treatment plant would serve the southern Participants and the Southern Water Supply Pipeline (remaining 74 percent of the total demand). Big Windsor Reservoir would serve as a terminal storage facility for both of these facilities, while Lonetree Reservoir would serve as supplemental terminal storage for the southern facility.

5.2.1.2 Water Supplies

Table 17 summarizes the water right transfers and associated existing storage within each system required to meet NISP firm yield delivery requirements to the North and South system Participants. As discussed in Section 3, estimates of transferrable consumptive use shown in the table were made using consumptive use calculations from the State's StateCU program as developed through the South Platte Decision Support System. Surface water consumptive use was reduced by the amount of estimated CU from historical C-BT deliveries to calculate transferable consumptive use.

Table 20. Recommended NAA - Water Rights Transfer Summary

Ditch	Transferable Ditch CU (AF/ac)	Irrigated Land Affected (acres)	Average Yield (AF)	Percent of Ditch	In-Ditch Storage Transferred (AF)
Larimer & Weld	0.54	36,800	19,900	58%	13,569
New Cache	0.97	22,000	21,300	60%	6,145
Home Supply	0.74	5,400	4,000	30%	5,998
Total	**0.70**	**64,200**	**45,200**	**55%**	**25,712**

During development of the 3 options, an assumption was made that based on existing water rights, exchanges could not be relied upon to provide a reliable water supply to the NAA. However, in actual operations, APOD or exchange water rights would be filed for the NAA, and water transferred from the Larimer & Weld and New Cache systems would be diverted through the Poudre Valley Canal when the APOD or exchange would not injure senior water rights to provide the higher quality source water for delivery and storage. Because hydrologic modeling has not yet been completed for the SDEIS, it is unknown when, how often and the quantities to which the APOD/exchange operations would take place in the future. Thus infrastructure is included to deliver all transferred water through existing diversion structures. However, the APOD/exchange operation should be included in the hydrologic analysis of the NAA in the SDEIS.

In addition to water rights transfers, a junior water right would be filed in the Poudre Basin. On average, this water right would yield about 900 AF per year. Based on the assumptions made regarding the implementation of existing conditional senior rights to this junior appropriation, it is estimated that the right would only be in priority during 3 of the 56 years in the study period (1980, 1983 and 1995). This water would be diverted through the existing Poudre Valley Canal to Cactus Hill Reservoir.

Total water supplies for the recommended NAA are approximately 45,200 AF. Consistent with the Proposed Action, the annual delivery to NISP Participants is 40,000 acre-feet. The 5,200 AF of water supplies that are in excess of the 40,000 AF required for delivery to the Participants would be consumed as evaporation in the reservoirs, or spilled when the transferred agricultural water is available during times when carryover storage is full or there is inadequate conveyance capacity to the carryover storage reservoir.

5.2.1.3 Infrastructure Requirements

The recommended NAA would utilize both existing and new infrastructure. Existing infrastructure would include existing diversion structures and canal systems and use of existing reservoirs that are a part of each ditch system's infrastructure. New infrastructure required for the recommended NAA includes a new, large reservoir, raw water pipelines and pump stations, construction of two regional water treatment plants, and both treated and untreated water delivery pipelines. A description of this infrastructure is presented below.

Storage

Water would be stored in existing reservoirs that are part of the Larimer & Weld, New Cache, and Home Supply systems. Regulating, carryover, and terminal storage would be held in pro-rata ownership in several reservoirs connected to these systems, including the Larimer and Weld high mountain system, the Poudre Valley Canal system, Terry Lake, Timnath Reservoir, Big Windsor Reservoir, Lonetree Reservoir, Mariano Reservoir, and Lon Hagler Reservoir. Big Windsor Reservoir would be a key facility in the plan, serving as a terminal storage facility for the north water treatment plant, and partially serving as terminal storage for the south water treatment plant. Lonetree Reservoir would be the other key reservoir, as it would serve as terminal storage for the south water treatment plant. Reservoirs would be operated in a manner to optimize water quality. This would require rotating releases among reservoirs to prevent evapoconcentration of salts from occurring in any one reservoir.

Cactus Hill Reservoir, at 120,000 AF, would be constructed to store water from the Poudre River system. Details regarding Cactus Hill Reservoir are contained in the DEIS.

Conveyance

New pipelines and pump stations required for the recommended NAA are summarized in Table 21.

Table 21. New Pipelines and Pump Stations Required for Recommended NAA

Segment	Capacity (cfs)	Diameter (inches)	Length (miles)	Pump Stations
Raw Water - Cactus Hill Reservoir Inlet	200	48	6	1 @ 7,700 HP
Raw Water - Cactus Hill Reservoir to North Water Treatment Plant (bidirectional)	80 (north) 60 (south)	42	9	1 @ 3,400 HP
Raw Water - New Cache to North Water Treatment Plant	110	66	4	1 @ 1,300 HP
Finished Water - North Water Treatment Plant to FCLWD / Evans	5-21	16-30	17	1 @ 500 HP
Finished Water - North Water Treatment Plant to Eaton	4	14	9	1 @ 70 HP
Raw Water - North Water Treatment Plant to South Water Treatment Plant	110	66	21	1 @ 2,000 HP
Raw Water - Lonetree Reservoir to South Water Treatment Plant	20	36	15	1 @ 100 HP
Finished Water - South Water Treatment Plant to CWCWD	10	20	11	1 @ 100 HP
Finished Water - South Water Treatment Plant to Lafayette	5-44	20-48	24	1 @ 2,000 HP
Treated Water - South Water Treatment Plant to SWSP	21	36	5	--

Raw water from the New Cache system would be diverted from the Greeley No. 2 Ditch and pumped to the North Water Treatment Plant and Big Windsor Reservoir in a 4-mile pipeline with a capacity of approximately 110 cfs. Raw water would be pumped from Big Windsor Reservoir and the North Water Treatment Plant to the South Water Treatment Plant in a 21-mile pipeline, also with a capacity of approximately 110 cfs. Treated water from the North Water Treatment

Plant would be pumped to Severance, FCLWD, Windsor, Evans and Eaton through 17-miles pipeline with a range of capacities from 4 to 21 cfs.

Raw water would be pumped from Lonetree Reservoir to the South Water Treatment Plant via a 15-mile pipeline with a capacity of 20 cfs. From the South Water Treatment Plant, treated water would be pumped to CWCWD via an 11-mile, 10 cfs pipeline and to the Tri-Towns, LHWD, Erie, and Lafayette via a 24-mile pipeline with a capacity ranging from 5 to 44 cfs. Treated water would be delivered to the SWSP via a 5-mile pipeline with a capacity of 21 cfs. It is possible that water conveyed to the SWSP would be treated to a slightly different finished quality since SWSP water conveys raw water than treated water to the Participants.

Tie-in locations to existing systems would be determined by project Participants at the time of design, and most likely be at existing or future water storage tanks within the distribution systems. For purposes of cost estimates, it is assumed that water would be delivered to the nearest edge of the service area boundaries to proposed NAA infrastructure as shown in Map 5.

Advanced Water Treatment

The recommended NAA relies on water supplies of lower quality than the Proposed Action and generally lower quality than the Participants' current supplies. The average raw water TDS from the mass balance is 354 mg/L, less than the secondary MCL of 500 mg/L and the assumed water quality goal of 400 mg/L. Therefore, the two water treatment plants would not require RO. However, if supplies are diverted at the ditch headgates, the NAA would be obtaining 43 percent of supplies downstream of municipal wastewater discharges and developed areas. There is potential to improve NAA raw water quality by exchanging New Cache water to diversion points further upstream. The amount of water that can be exchanged is not known at this time because the NISP hydrologic model continues to be modified. Due to the potential for lower raw water quality, the Participants would likely construct advanced water treatment facilities.

There are a variety of potential water treatment designs that could be selected by the Participants to meet their water quality goals. One potential design would use the following treatment steps:

- Precipitative softening
- UV advanced oxidation
- Granular media filtration, and
- Carbon adsorption

Table 22 summarizes the advanced water treatment plant average and maximum month design flow rates.

Table 22. Recommended NAA Water Treatment Plant Summary

Segment	Average Month Flow (MGD)	Max Month Flow (MGD)
North Regional Advanced Water Treatment Plant	12.5	24.3
South Regional Advanced Water Treatment Plant	23.2	45.0
Total	**35.7**	**69.3**

5.3 Opinion of Probable Construction Cost

An opinion of probable construction cost for the recommended NAA is summarized in Table 23. MWH developed cost estimates for water rights acquisition and revegetation only. These costs are presented as a range due to the uncertainty in the future cost of purchasing large quantities of water. All other costs were estimated by Integra Engineering and GEI (2010a and 2010b) using engineering information provided by MWH. All estimates are at a conceptual level (see discussion in section 3.4).

Table 23. Recommended NAA Conceptual Level Cost Opinion

Component	Cost
Storage – Cactus Hill Reservoir	$120M
Water Treatment (beyond conventional)	$40M
Conveyance	$160M
Unlisted Items at 10%	$30M
Subtotal	$340M
Contingency at 25%	$90M
Base Construction Cost	$440M
Engineering, construction management, legal, administrative at 13%	$60M
Water Rights Acquisition & Revegetation	$300M - 400M
Total	**$800M – 900M**

5.4 No Action Alternative Implementation

Implementation of the NAA would differ from that of the Proposed Action due to the additional time required to procure a change agricultural water rights. Transfer of ditch shares from agricultural to municipal use would be a lengthy process for the Participants. The process would include initial studies and purchase offerings to individuals within the ditch companies involved, procurement of shares, a change case in water court, performing actual dry-up and revegetation, and finally, construction of facilities and delivery of water. This section describes the general process for how this type of transaction could occur. Note that these processes differ from ditch to ditch and project to project.

The initial steps in the irrigated lands transfer process would be to perform an initial analysis that would include a “due diligence” investigation into the legal status and sustainability of the potential water rights, perform initial engineering and hydrologic evaluations, and determine other legal issues. Once this investigation is complete, the Participants would solicit interest in purchasing ditch shares to the shareholders in the ditches involved. Several types of agreements could potentially be established during this initial offering, including an outright purchase of shares, first right of refusal on shares, and potentially, even some rotational fallowing types of arrangements with certain sub-sets of the ditch system.

It is likely that the initial offering and transfer of shares would not produce all of the water ultimately needed to meet yield requirements. However, enough shares would need to be required for the NISP Participants to be comfortable constructing the facilities that are needed to deliver the water. Participants would likely have a standing offer with shareholders for purchase of shares as they become available. Because precedence would be set through the initial water court proceedings regarding the change in point of diversion and use, water court proceedings would become more streamlined for subsequent share purchases and speed the change process for these shares. Based on the current hydrologic conditions, economic conditions, competition for water, status of other water supply projects, and other issues beyond the Participants' control, securing an adequate level of water to justify construction of facilities could take years.

Points-of-diversion and allowable uses for those ditch shares purchased would need to be "changed" in the Colorado water court system. The City of Thornton underwent a similar type of change when they purchased and changed shares of the Water Supply and Storage Company (case nos. 86CW401, 86CW402, 86CW403, and 87CW332, Division 1 Water Court) which took about 8 years to complete. Although the process for making ditch-wide changes in water court has matured substantially since that time, the magnitude of change and numerous parties involved will result in a process that will likely take 5 to 7 years to resolve. Changing points-of-diversions and allowable uses would require an engineering evaluation to ensure that no senior water rights are injured by the proposed change, and would include historical consumptive use evaluations, return flow evaluations, operational investigations and other technical analyses to prove non-injury. Some of the existing system storage would likely be required to meet return flow obligations.

Dry-up and revegetation would likely be required for most shares purchased. The only case where a dry-up and revegetation clause would not be required would be if the land were to ultimately be developed for municipal use, which in this case, would only be a small percentage of the land. In any case, irrigated agriculture would need to cease on these lands before NISP Participants could take delivery of the water. Dry-up could consist of either reestablishing native vegetation on the acreages involved, or conversion of farming practices to dry-land practices, such as winter wheat.

Delivery of water from these rights could only be made after all water court proceedings and revegetation requirements are complete. Because of the uncertain nature in these types of change cases, it is likely that the Participants would choose not to construct facilities until the entire change case is complete and any appeals are settled. Most of the options investigated in this report do not lend themselves well to staging – that is, nearly all of the facilities would need to be constructed to deliver water. For certain Participants, it may be possible to implement interim measures to take delivery of some water prior to completion of facilities.

Construction of facilities would likely commence with the construction of the pipeline segment from New Cache to Big Windsor Reservoir and the northern water treatment plant, and the pipeline segment from Lonetree Reservoir to the southern water treatment plant. All delivery infrastructure from the water treatment plants to the Participants would need to be constructed at this time as well. Because the water supplied by Home Supply would only supply a limited amount of demand, the pipeline segment from Big Windsor Reservoir to the southern water treatment plant would need to be constructed soon after. The last facility to be constructed would likely be the Cactus Hill Reservoir structure and associated infrastructure.

6 Summary

This analysis was undertaken to develop and provide details for a recommended NAA for use in the NISP SDEIS. The recommended NAA was developed through a systematic process that considered reasonable water supply, storage, conveyance and water treatment concepts which were combined into options that met the full 40,000 AF annual delivery requirement required by NISP. The options were then screened using a qualitative process to develop the final selected NAA. The Participants and Northern Water were engaged in the process through individual meetings, presentation of preliminary and final concepts, consideration of comments and specific requirements in the screening and evaluation process, and selection of the NAA for the SDEIS.

The recommended NAA primarily consists of ag transfers from the Larimer & Weld, New Cache and Home Supply systems; storage in existing agricultural reservoirs; a new storage facility at the Cactus Hill reservoir site (as evaluated in the DEIS); two regional advanced water treatment plants; and associated pipelines and pump stations to deliver raw and treated water to the Participants. The ag transfers would result in the dry-up of nearly 60 percent of the Larimer & Weld and New Cache irrigation systems in the Poudre River Basin east of Fort Collins and north of Greeley, and approximately 30 percent of the Home Supply system, which, when combined with transfers by others, would dry-up nearly 85 percent of the lands served by the Home Supply system between Berthoud and Johnstown. The estimated cost of the NAA ranges from $800 – 900 million.

Implementation of the NAA would differ from that of the Proposed Action due to the additional time required to procure and change agricultural water rights. Transfer of ditch shares from agricultural to municipal use would be a lengthy process for the Participants. It would include initial studies and purchase offerings to individuals within the ditch companies involved, procurement of shares, a change case in water court, performing actual dry-up and revegetation, and finally, construction of facilities and delivery of water. Because of the uncertainty involved in water rights procurement and change cases, it is likely that the Participants would choose not to construct facilities until an adequate quantity of shares were purchased to justify construction and the entire change case was complete.

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Appendix A – Preliminary NAA Options Schematics

<u>Preliminary Regional Concepts - Summary</u>
NISP No Action Alternative Development

Summary of Preliminary Concepts:

Concept	Concept Description	Water Supply		New Storage (ac-ft)
		Irrigated Land Purchase (ac)	Yield (ac-ft)	
A	Local Supplies, Local storage	50,600	49,000	59,000
B.1	Balanced Ag Purchase, Existing Storage	76,600	64,000	0
B.2	Northern Ag Purchase, Existing Storage, New Plains Reservoir	60,500	49,000	44,000
B.3	Northern Ag Purchase, New Foothills Reservoir	59,400	49,000	93,000
B.4	Northern Balanced Ag Purchase, Existing Storage, New Plains Reservoir	51,900	44,000	19,000
C	South Platte Conjuctive Use Project	43,000	44,000	54,000

Notes:

(1) Alternatives are conceptual in nature, with estimated consumptive use estimates and storage requirements. Values may vary during alterantive development phase.

(2) CU yields based on SPDSS analysis of likely available water sources in Poudre and Big Thompson, and average of basin CU for other basins.

(3) Storage requirements based on simple mass-balance model that utilizes historical CU and estimates of purchased yield for the Poudre and Big Thompson basins. St. Vrain and Boulder Creek ditches are not included in the analysis. Simple estimates were used for these basins.

(4) All analyses will be refined based upon selected concepts.

(5) Concepts can be combined.

General Discussion:

- Water quality decreases as the amount of storage in plains reservoirs increases (lower inflow WQ, agricultural runoff, evapoconcentration).
- Boulder Creek and St. Vrain basins have limited irrigated land purchase potential and limited storage availability.
- Storage in existing facilities is needed to deliver CU purchase. Some storage in existing facilities could be used for regulating storage (storage required to meet monthly demands). However, existing facilities typically do not provide adequate carryover storage (i.e. drought storage).
- CU and storage requirements can vary greatly depending upon particular irrigation systems assumed for purchase.
- Purchase within multiple irrigation systems diversifies overall portfolio, but will have higher infrastructure costs.

Preliminary Regional Concept
NISP No Action Alternative Development

Concept: A - Local Supplies, Local storage

General Description:
This alternative is similar to the exiting NISP No Action Alternative. It would involve purchases of local supplies and construction of facilities necessary to store and transport this water to participants. Purchases are aligned along geographic areas. Southern participants would be supplied with mostly South Platte water due to limited water supply opportunities in Boulder County.

Components:
Water Supplies
Average Yield Required: *49,000 af*
Firm Yield Required: *44,000 af*

Source	CU Yield (ac-ft/ac)	Purchase Acres	Average Yield (ac-ft)
Poudre	0.80	22,500	18,000
Big Thompson	0.90	4,400	4,000
St. Vrain	0.97	3,100	3,000
Boulder Creek	0.95	2,100	2,000
South Platte	1.19	18,500	22,000
Total	0.97	50,600	49,000

Storage
Total Storage Required: *77,000 af*
New Storage Required: *59,000 af*

Representative Potential Facilities			
Site	Site Name	Basin	Vol (af)
Exist	Existing ag storage facilities	All	18,000
14	Wildcat Reservoir	St. Vrain River	34,800
43	Cobb Lake Enlargement	Cache la Poudre River	39,500
48	Hertha Reservoir Enlargement	Big Thompson River	74,300
77	Potato Hill	St. Vrain River	5,000
116	Lykins Gulch	St. Vrain River	20,000

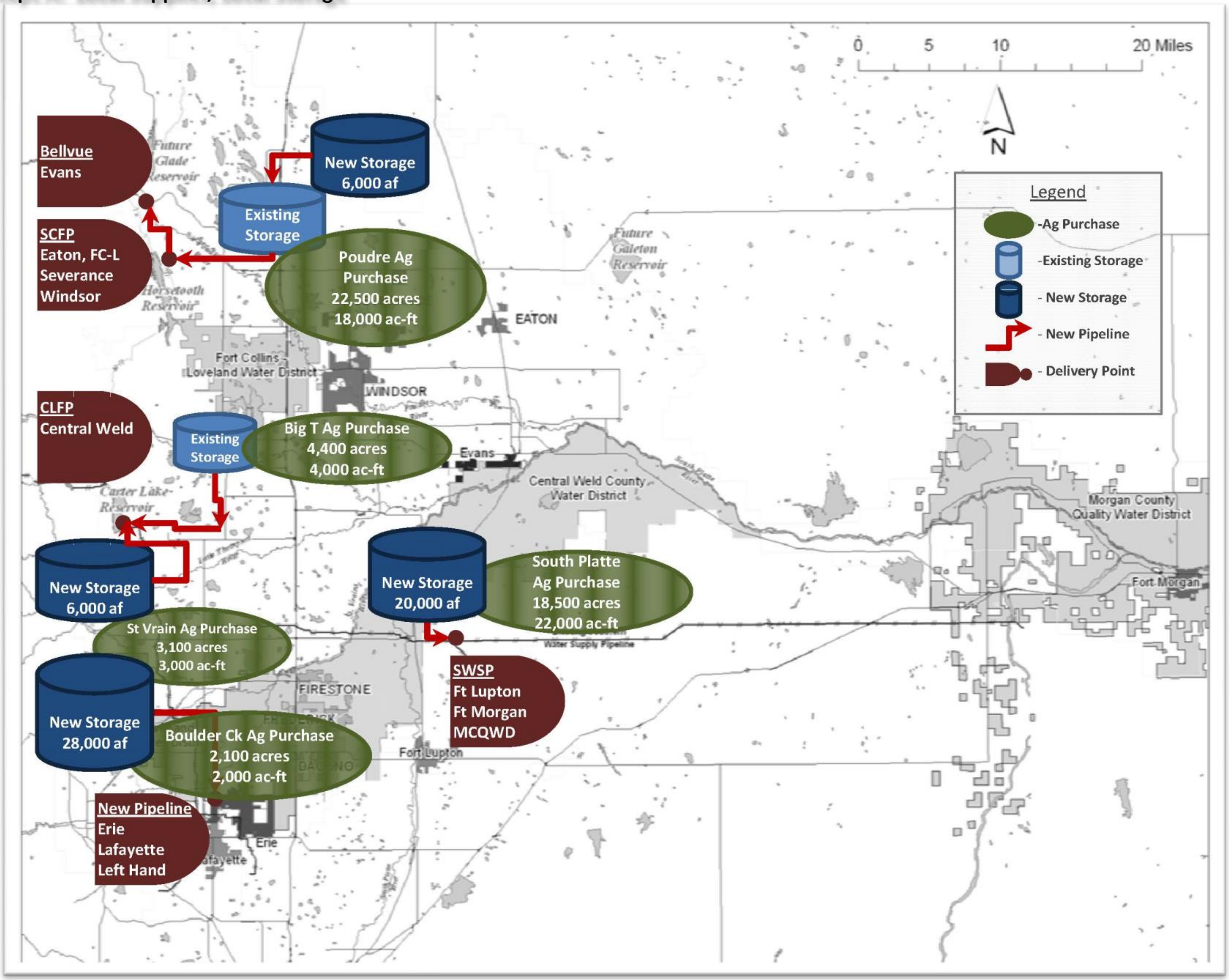
Note: Assumes portion of regulatory storage in existing facilities, and regulatory and carryover storage in new facility.

Delivery and Treatment

Entities	Description
Eaton, Fort Collins-Loveland, Severance, Windsor	Pipeline or exchange to Pleasant Valley Pipeline, delivery to Soldier Canyon Filter Plant.
Evans	Pipeline or exchange to Pleasant Valley Pipeline, delivery to Bellvue Water Treatment Plant
Fort Lupton, Fort Morgan, Morgan County Quality Water	Pipeline from South Platte reservoir to Southern Water Supply Pipeline
Central Weld, Firestone	Pipeline from new reservoir to Carter Lake Filter Plant.
Erie, Lafayette, Left Hand	Pipeline from new reservoir to existing water treatment plants.

Discussion:
- Likely water quality issues due to storage in plains reservoir facilities.
- Not a regional project.
- Boulder Creek and St. Vrain ditches have minimal available storage - would require additional new storage.

Concept A: Local Supplies, Local Storage



Preliminary Project Concept
NISP No Action Alternative Development

Concept: B.1 - Balanced Ag Purchase, Existing Storage

General Description:
This alternative would consist primarily of Poudre and Big Thompson water supplies, and utilize only existing irrigation system reservoir storage. It is assumed that purchases of agricultural water would include purchasing pro-rata shares in available storage facilities.

Components:
Water Supplies
Average Yield Required: *64,000 af*
Firm Yield Required: *44,000 af*

Source	CU Yield (ac-ft/ac)	Purchase Acres	Average Yield (ac-ft)
Poudre	0.80	52,500	42,000
Big Thompson	0.90	18,900	17,000
St. Vrain	0.97	3,100	3,000
Boulder Creek	0.95	2,100	2,000
South Platte	1.19	0	0
Total	0.84	76,600	64,000

Storage
Total Storage Required: *54,000 af*
New Storage Required: *0 af*

Representative Potential Facilities			
Site	Site Name	Basin	Vol (af)
Exist	Existing ag storage facilities	All	54,000

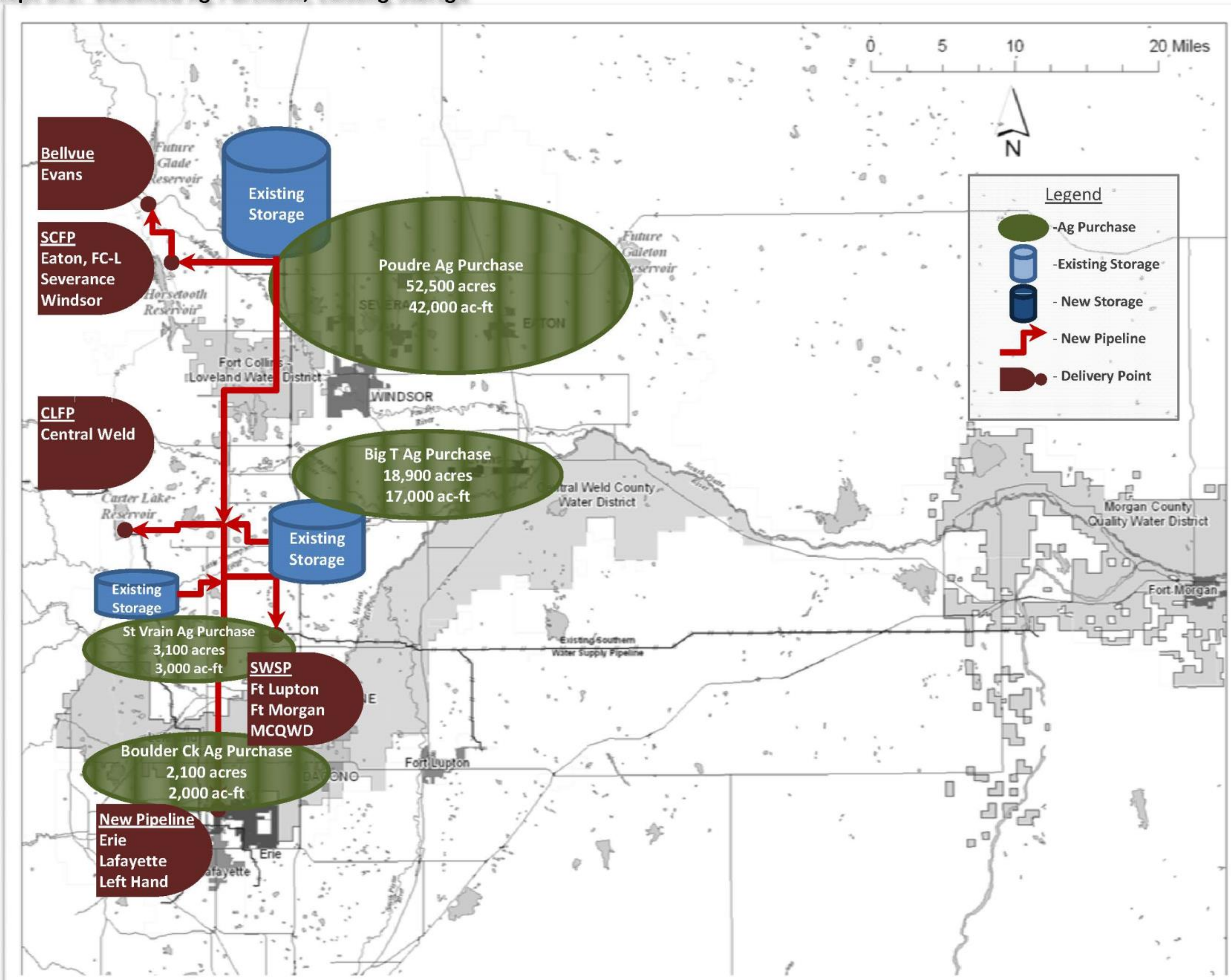
Note: Assumes regulatory and carryover storage in existing facilities.

Delivery and Treatment

Entities	Description
Eaton, Fort Collins-Loveland, Severance, Windsor	Pipeline or exchange to Pleasant Valley Pipeline, delivery to Soldier Canyon Filter Plant.
Evans	Pipeline or exchange to Pleasant Valley Pipeline, delivery to Bellvue Water Treatment Plant
Fort Lupton, Fort Morgan, Morgan County Quality Water	Pipeline connection to Southern Water Supply Pipeline
Central Weld, Firestone	Pipeline or exchange to Pleasant Valley Pipeline, delivery to Bellvue Water Treatment Plant
Erie, Lafayette, Left Hand	Pipeline to existing water treatment plants.

Discussion:
- Likely water quality issues due to storage in plains reservoir facilities.
- No dedicated terminal storage. High risk during infrastructure outages.
- No dedicated carryover storage. High risk during drought conditions.
- Some purchased water may not be usable.
- Boulder Creek and St. Vrain ditches have minimal available storage - increases drought vulnerability, and amount of ag purchased.

Concept B.1: Balanced Ag Purchase, Existing Storage



Preliminary Project Concept
NISP No Action Alternative Development

Concept: B.2 - Northern Ag Purchase, Existing Storage, New Plains Reservoir

General Description:
This alternative would consist of Poudre and Big Thompson water supplies, and utilize to the maximum extent possible storage availability in existing irrigation system reservoirs. It is assumed that purchases of agricultural water would include purchasing pro-rata shares in available storage facilities.

Components:
Water Supplies
Average Yield Required: *49,000 af*
Firm Yield Required: *44,000 af*

Source	CU Yield (ac-ft/ac)	Purchase Acres	Average Yield (ac-ft)
Poudre	0.80	53,800	43,000
Big Thompson	0.90	6,700	6,000
St. Vrain	0.97	0	0
Boulder Creek	0.95	0	0
South Platte	1.19	0	0
Total	0.81	60,500	49,000

Storage
Total Storage Required: *61,000 af*
New Storage Required: *28,000 af*

Representative Potential Facilities			
Site	Site Name	Basin	Vol (af)
Exist	Existing ag storage facilities	Poudre, Big Thompson	33,000
23	Highland No. 2	Big Thompson River	3,300
43	Cobb Lake Enlargement	Cache la Poudre River	39,500
44	North Poudre No. 5 and 6 Enlargement	Cache la Poudre River	48,470
48	Hertha Reservoir Enlargement	Big Thompson River	74,300

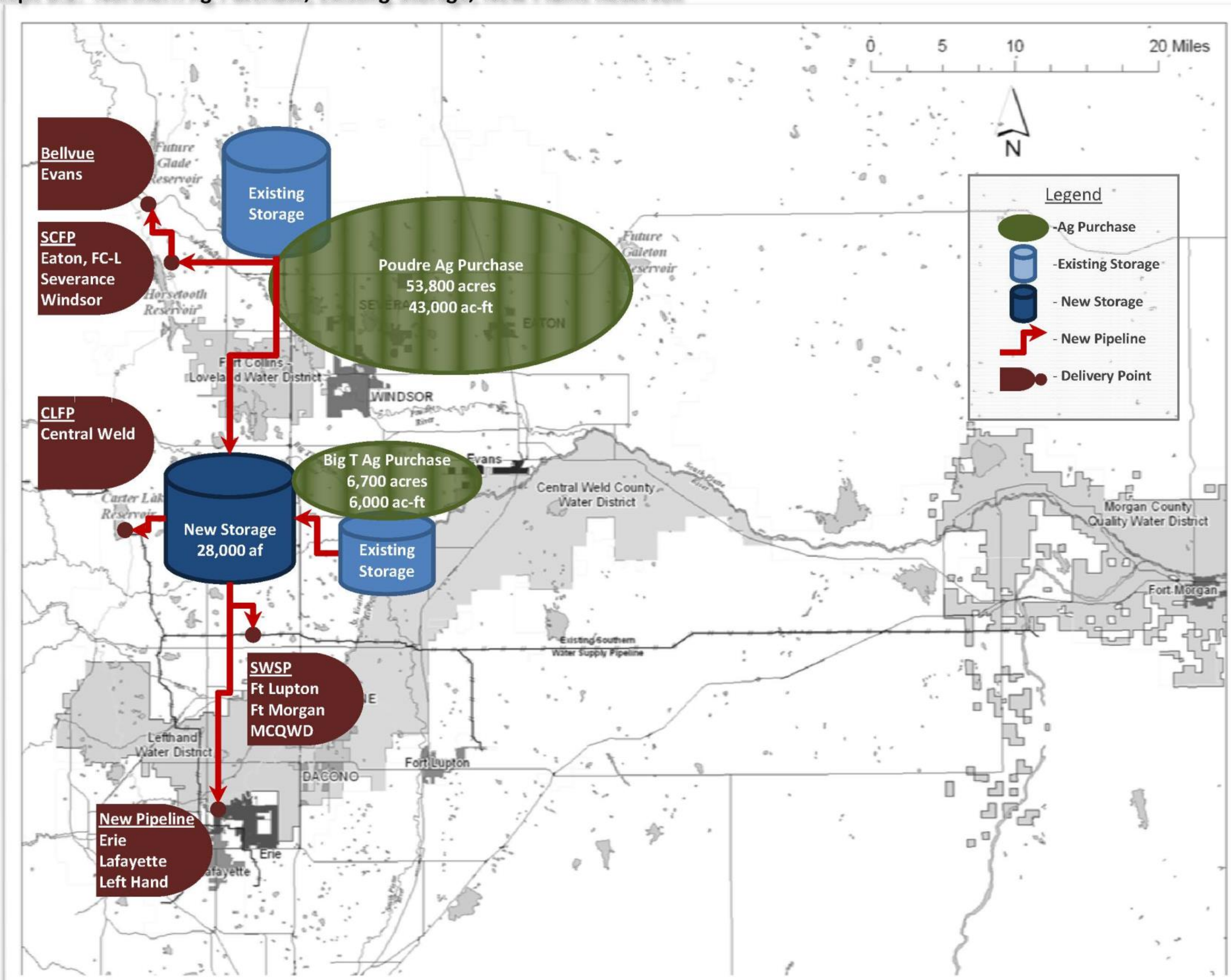
Note: Assumes regulatory storage in existing facilities, carryover storage in new facility. Potential terminal storage in Big Thompson Basin with carryover storage in Poudre Basin.

Delivery and Treatment

Entities	Description
Eaton, Fort Collins-Loveland, Severance, Windsor	Pipeline or exchange to Pleasant Valley Pipeline, delivery to Soldier Canyon Filter Plant.
Evans	Pipeline or exchange to Pleasant Valley Pipeline, delivery to Bellvue Water Treatment Plant
Fort Lupton, Fort Morgan, Morgan County Quality Water	Pipeline or exchange to Pleasant Valley Pipeline, delivery to Bellvue Water Treatment Plant
Central Weld, Firestone	Pipeline connection to Carter Lake Filter Plant.
Erie, Lafayette, Left Hand	Pipeline to existing water treatment plants.

Discussion:
- Potential water quality concerns due to storage in plains reservoir facilities.
- Would provide dedicated carryover and terminal storage.

Concept B.2: Northern Ag Purchase, Existing Storage, New Plains Reservoir



Preliminary Project Concept
NISP No Action Alternative Development

Concept: B.3 - Northern Ag Purchase, New Foothills Reservoir

General Description:
This alternative would consist of Poudre and Big Thompson water supplies diverted at canyon mouths. Utilize existing irrigation system reservoirs only as necessary to facilitate deliveries to a larger new reservoir. It is assumed that purchases of agricultural water would *minimal* purchase of shares in available storage facilities.

Components:
Water Supplies
Average Yield Required: *49,000 af*
Firm Yield Required: *44,000 af*

Source	CU Yield (ac-ft/ac)	Purchase Acres	Average Yield (ac-ft)
Poudre	0.80	43,800	35,000
Big Thompson	0.90	15,600	14,000
St. Vrain	0.97	0	0
Boulder Creek	0.95	0	0
South Platte	1.19	0	0
Total	0.82	59,400	49,000

Storage
Total Storage Required: *103,000 af*
New Storage Required: *93,000 af*

Representative Potential Facilities			
Site	Site Name	Basin	Vol (af)
Exist	Existing ag storage facilities	Poudre, Big Thompson	10,000
48	Hertha Reservoir Enlargement	Big Thompson River	74,300
155	Meadow Hollow Big Thompson River Mead	Big Thompson River	60,000
156	Dry Creek Big Thompson River Dry Creek	Big Thompson River	62,300
171	Sprenger Ranch Big Thompson River	Big Thompson River	92,700
172	Chimney Hollow Big Thompson River Yes 11	Big Thompson River	110,000
178	Dowe Flats St. Vrain River	St. Vrain River	119,000

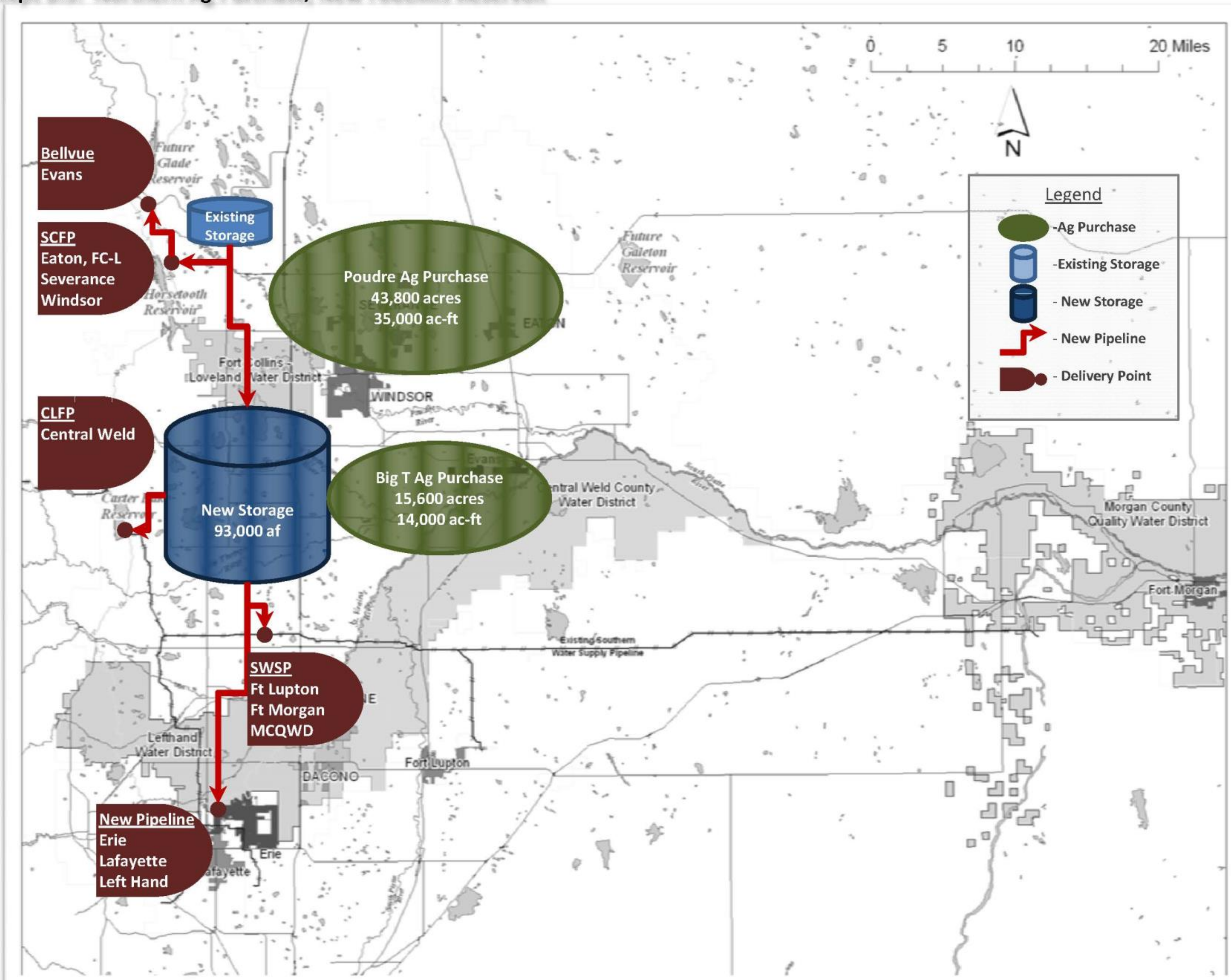
Note: Assumes regulatory and carryover storage in new reservoir, as well as an equivalent amount of ag purchase storage in new reservoir. Will require some regulatory storage at diversion to reduce conveyance facility size.

Delivery and Treatment

Entities	Description
Eaton, Fort Collins-Loveland, Severance, Windsor	Pipeline or exchange to Pleasant Valley Pipeline, delivery to Soldier Canyon Filter Plant.
Evans	Pipeline or exchange to Pleasant Valley Pipeline, delivery to Bellvue Water Treatment Plant
Fort Lupton, Fort Morgan, Morgan County Quality Water	Pipeline connection to Southern Water Supply Pipeline
Central Weld, Firestone	Pipeline connection to Carter Lake Filter Plant.
Erie, Lafayette, Left Hand	Pipeline to existing water treatment plants.

Discussion:
- Likely best water quality of any concept due to diversion at canyon mouth and storage in large, deep reservoir.
- Large (and likely costly) delivery system to reservoir would be required.
- Would provide dedicated carryover and terminal storage.
- May be difficult to develop this volume of storage in a single facility without major federal action.

Concept B.3: Northern Ag Purchase, New Foothills Reservoir



Preliminary Project Concept
NISP No Action Alternative Development

Concept: B.4 - Northern Balanced Ag Purchase, Existing Storage, New Plains Reservoir

General Description:
This alternative would consist of Poudre and Big Thompson water supplies, and utilize to the maximum extent possible storage availability in existing irrigation system reservoirs. It is assumed that purchases of agricultural water would include purchasing pro-rata shares in available storage facilities.

Components:
Water Supplies
Average Yield Required: *44,000 af*
Firm Yield Required: *44,000 af*

Source	CU Yield (ac-ft/ac)	Purchase Acres	Average Yield (ac-ft)
Poudre	0.80	27,500	22,000
Big Thompson	0.90	24,400	22,000
St. Vrain	0.97	0	0
Boulder Creek	0.95	0	0
South Platte	1.19	0	0
Total	0.85	51,900	44,000

Storage
Total Storage Required: *71,000 af*
New Storage Required: *19,000 af*

Representative Potential Facilities			
Site	Site Name	Basin	Vol (af)
Exist	Existing ag storage facilities	All	52,000
46	Modified Chimney Hollow	Big Thompson River	20,000
48	Hertha Reservoir Enlargement	Big Thompson River	74,300
124	Pole Hill Road	Big Thompson River	25,300
155	Meadow Hollow Big Thompson River Mead	Big Thompson River	60,000

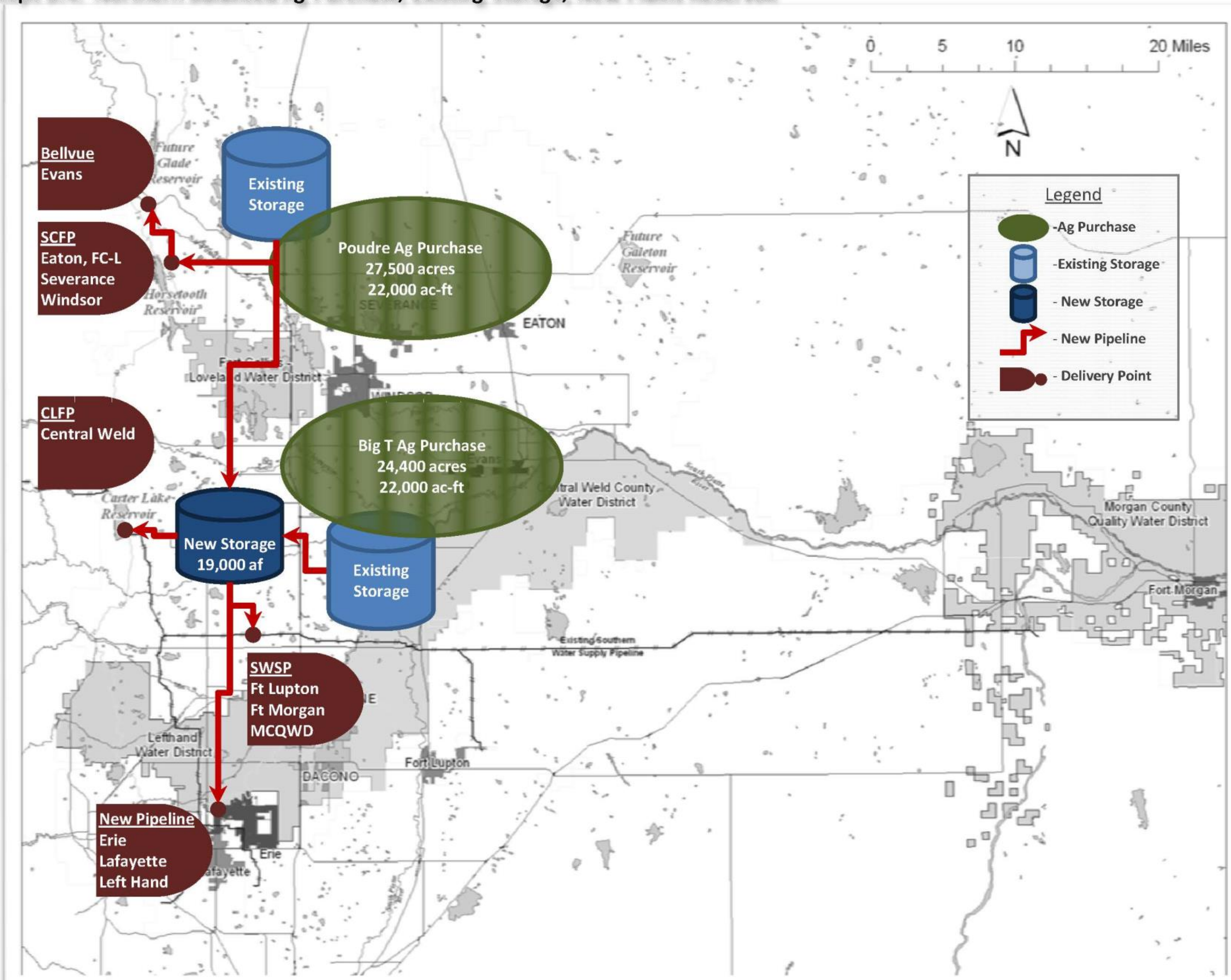
Note: Assumes regulatory storage in existing facilities, carryover storage in new facility.

Delivery and Treatment

Entities	Description
Eaton, Fort Collins-Loveland, Severance, Windsor	Pipeline or exchange to Pleasant Valley Pipeline, delivery to Soldier Canyon Filter Plant.
Evans	Pipeline or exchange to Pleasant Valley Pipeline, delivery to Bellvue Water Treatment Plant
Fort Lupton, Fort Morgan, Morgan County Quality Water	Pipeline connection to Southern Water Supply Pipeline
Central Weld, Firestone	Pipeline connection to Carter Lake Filter Plant.
Erie, Lafayette, Left Hand	Pipeline to existing water treatment plants.

Discussion:
- Potential water quality concerns due to storage in plains reservoir facilities.
- Would provide dedicated carryover and terminal storage.
- Lower new storage requirements (depends on ability to buy into Greeley-Loveland System).

Concept B.4: Northern Balanced Ag Purchase, Existing Storage, New Plains Reservoir



Preliminary Project Concept
NISP No Action Alternative Development

Concept: C - South Platte Conjuctive Use Project

General Description:
For the Southern and Eastern participants, this alternative is similar to Aurora's "Prairie Waters" project in that water would be pumped from shallow alluvium into an infiltration basin along the South Platte. Then, water would be pumped from this basin to the participants. Unlike "Prairie Waters," this alternative would rely on ag purchases rather than reusable return flows for water supplies. For the Northern participants, ag purchases and minimal new storage would be required.

Components:
Water Supplies
Average Yield Required: 44,000 af
Firm Yield Required: 44,000 af

Source	CU Yield (ac-ft/ac)	Purchase Acres	Average Yield (ac-ft)
Poudre	0.80	13,800	11,000
Big Thompson	0.90	3,300	3,000
St. Vrain	0.97	1,000	1,000
Boulder Creek	0.95	2,100	2,000
South Platte	1.19	22,800	27,000
Total	1.02	43,000	44,000

Storage
Total Storage Required: 61,000 af
New Storage Required: 54,000 af

Representative Potential Facilities			
Site	Site Name	Basin	Vol (af)
Exist	Existing ag storage facilities	All	7,000
14	Wildcat Reservoir	St. Vrain River	34,800
15	Big Kammerzell Reservoir	Big Thompson River	94,100
108	Frederick	St. Vrain River	17,900

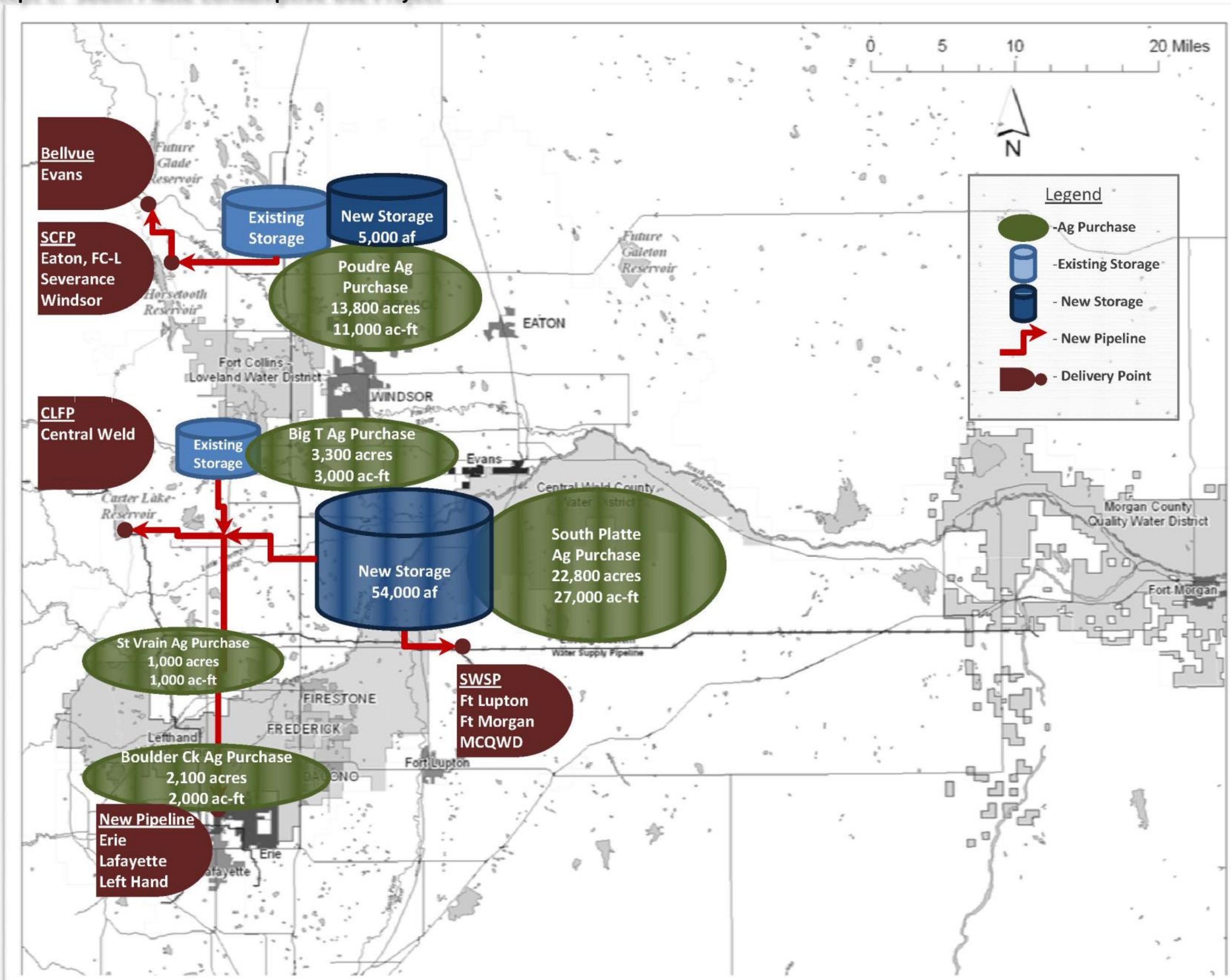
Note: Assumes portion of regulatory storage in existing facilities, and regulatory and carryover storage in new facility.

Delivery and Treatment

Entities	Description
Eaton, Fort Collins-Loveland, Severance, Windsor	Pipeline or exchange to Pleasant Valley Pipeline, delivery to Soldier Canyon Filter Plant.
Evans	Pipeline from new reservoir to new water treatment plant.
Fort Lupton, Fort Morgan, Morgan County Quality Water	Pipeline from new reservoir to Southern Water Supply Pipeline.
Central Weld, Firestone	Pipeline from new reservoir to Carter Lake Filter Plant.
Erie, Lafayette, Left Hand	Pipeline from new reservoir to existing water treatment plants.

Discussion:
- Likely water quality issues due to S. Platte water supplies and storage in plains reservoir facilities.
- This project is a more proven project for consistent water supplies, such as reusable return flows.
- Has potential to enhance use of reusable return flows.

Concept C: South Platte Consumptive Use Project



Appendix B – Water Quality Summary and Considerations

Table B-1 summarizes the range and average of surface water constituents for important drinking water parameters for the following locations related to the NAA:

- **Horsetooth Reservoir** – as an indicator of the current raw water quality typical of most Participants and raw water quality likely for the Proposed Action
- **Poudre River at Canyon Mouth** – as an indicator of the raw water quality likely from a Poudre River canyon mouth diversion
- **Poudre River near Timnath** – as an indicator of irrigation diversion downstream of Fort Collins
- **S. Platte River at Henderson** – as an indicator of the raw water quality in the eastern Front Range
- **Big Thompson River below Power Plant** – as an indicator of the raw water quality for a diversion near the Big Thompson canyon mouth

Table B-1. Raw Water Quality Summary - Range and Average of Constituents

Location	TDS (mg/L)	Total Organic Carbon (mg/L)	Nitrate plus Nitrite (mg/L)	Hardness (mg/L as $CaCO_3$)
Horsetooth Reservoir[1]	20-78 (range) 53 (average)	0-12.6 2.9	0- 0.235 0.14	9.6-52 30
Poudre River at Mouth of Canyon[1]	21-195 74	0.1-2.18 0.44	0- 0.5 0.12	13-89 47.5
Poudre River near Timnath[2]	60-1,501 749	2.9-3.2 3.1	0.04-2.85 0.79	36-1,200 562
S. Platte River at Henderson[2]	137-668 419	7.0-41.3 13.7	1.0-5.1 2.8	84-380 169
Big Thompson River below Power Plant[3]	15-92 39	2.7-9.5 4.0	0-0.6 0.20	9-33 30

Sources:

(1) Corps (2008b). Horsetooth Reservoir, period 1997 to 2006; Cache la Poudre at Mouth of Canyon (USGS gage 06752000), period 1980 to 2004.

(2) USGS (2009). Cache la Poudre Riv ab Boxelder Crk nr Timnath, CO (USGS gage 06752280), period 2000 to 2009; S. Platte River at Henderson, CO (USGS gage 06720500), period 1999 to 2009. After reviewing EPA's STORET website and USGS NWIS, MWH did not find a site more representative of a likely S. Platte River diversion location, such as near Fort Lupton or Platteville, with recent water quality data. Henderson is the farthest downstream location upstream of Greeley and the Poudre confluence.

(3) Big Thompson Watershed Forum (2009). Big Thompson R blw BG T Power Plant nr Loveland (M80), period 2001 to 2007, nitrate plus nitrite in dissolved form.

Note: TDS in mg/L estimated as specific conductance in ug/L * 0.67.

None of the Participants have documented finished water quality goals beyond compliance with drinking water standards and providing the highest quality water possible. Some of the Participants currently provide water to their customers from different water treatment plants. Participants stated that differences in water taste or odor can sometimes be detected by customers and can result in complaints. Therefore, they would like NISP water to be indistinguishable from their current supplies.

The major concerns with surface water diverted or stored in the Northeastern Front Range are:

- Location downstream of municipal and irrigation return flows, which can contain numerous constituents of concern including nitrate, pathogens, organics, and micropollutants including pharmaceuticals and personal care products. Some of these constituents are currently regulated in Colorado; others are of emerging concern to consumers and water providers.
- **Total dissolved solids (TDS)** – the amount of salts dissolved in water, generally increases with distance from the mountains. Although the increase in concentration with distance is typical of many water constituents, TDS presents a unique challenge because it can only be removed using RO.
- Storage in shallow reservoirs presents two major drinking water challenges. First, the relatively large surface area promotes evaporation of the stored water; not only reducing the amount of water available for drinking water use, but concentrating dissolved constituents in the water. Secondly, a large fraction of the water is in the photic zone, where light is able to penetrate, and is warmed by the atmosphere, both of which facilitate algae growth. Excessive algae growth can result in many drinking water treatment challenges affecting both health and aesthetics; algae can cause taste problems and organic matter can lead to the formation of disinfection byproducts (discussed below). Additionally, algae can result in low dissolved oxygen and releases of minerals such as manganese and iron from bottom sediments.

TDS, organic matter, and hardness are discussed in further detail below as examples of constituents likely requiring additional treatment as NAA water supplies:

<u>TDS</u>:

The secondary water quality standard for TDS is 500 mg/L. However, some Front Range water providers with plans to use South Platte water for part of their water supply have set treated water quality goals less than 500 mg/L:

- East Cherry Creek Valley (ECCV) Water and Sanitation District's Northern Water Project has a TDS goal of 300 mg/L, which is substantially higher than the ECCV current treated water concentration of 100 mg/L (ECCV 2008).
- The City of Aurora's Prairie Waters Project has a finished water TDS goal (after blended with Aurora's other supplies) of 400 mg/L, which compares to its current water supply TDS of about 175 mg/L (Carter et al. 2006). Aurora wanted its new water source to not only exceed water quality standards, but be "indistinguishable" from its current supply. Aurora confirmed its TDS goal through taste testing.

<u>Organic Matter</u>:

The presence of organic matter in the water is problematic because when combined with chlorine or other disinfectants at the water treatment plant disinfection byproducts (DBPs) are produced. Many of these DBPs have been determined to be carcinogenic. Keeping total organic carbon (TOC) levels low results in less DBP formation. Drinking water standards require removal of 50 percent of TOC through treatment for raw water with TOC levels greater than 8.0 mg/L. The Horsetooth and Poudre River diversion locations would not require TOC removal, but the South Platte River location would.

Hardness:

Hardness is a measure of the multivalent cations in water. High hardness can make precipitation in water treatment difficult and also can result in scale formation. There is no water quality standard for hardness, but water hardness has been classified as follows:

- Soft: 0 to <50 mg/L as $CaCO_3$
- Moderately Hard: 50 to <100 mg/L as $CaCO_3$
- Hard: 100 to <150 mg/L as $CaCO_3$
- Very Hard: >150 mg/L as $CaCO_3$ (Source: MWH 2005)

The USEPA (1986) classifies hardness concentrations of 300 mg/L as $CaCO_3$ and up as "very hard."

With hardness levels less than 50 mg/L as $CaCO_3$, the Horsetooth and Poudre River water would be considered soft. The South Platte River water would be considered hard or very hard. As with TDS, the City of Aurora and ECCV have set hardness goals for their new projects of 150 mg/L and 100 mg/L as $CaCO_3$, respectively.

NISP NAA Water Quality Considerations

As summarized above, some of the potential NAA water sources would present water treatment challenges. For constituents other than TDS, there are different potential treatment technologies that could be implemented to meet water quality standards and goals. Rather than evaluate potential treatment technologies for the different water sources, the NAA analysis uses treatment plant designs implemented by other municipalities for similar water sources as examples of what the Participants could do for advanced water treatment of NAA water supplies.

Appendix C – Ditch Share Acquisition Costs and Maximum Transfer

Ditch Share Acquisition Costs

For purposes of ditch share acquisition cost estimates, the study area was divided into three areas: the Poudre Basin, the Big Thompson Basin and the Denver Metro Area. Cost information for each of these areas is discussed in the following sections.[3]

It should be noted that the cost information presented in this discussion is primarily for transactions of small amounts of water. The highest transaction amount found was for slightly more than 200 acre-feet of water. This is over two orders of magnitude less than the amount of water that would need to be purchased as part of the NAA. Several of the discussions with experts concluded that large because any of the alternatives would involve the purchase of substantial portion of the shares in a given system, increases in share cost beyond those reported for small numbers of shares due to simple supply and demand economics. However, it is difficult to determine the level of market adjustments. For purposes of this analysis, a 25 percent adjustment was assumed (see following paragraph for discussion).

In addition to transactions of ditch shares, transactions of C-BT units are also useful to review when establishing costs of water along the Northern Front Range. A summary of C-BT unit prices and price with an average annual quota of 70% is presented in Figure C-1. C-BT prices provide valuable information in several different manners.

- Historically, C-BT prices have been a good indicator of market activity and provide a general indication of the upper level of water costs over a longer period of time, with the rationale that historically, if entities within the District were faced with water costs greater than C-BT unit costs, they would simply prefer C-BT units. This isn't always the case, as there are other multiple use systems that provide other benefits to specific to certain water systems. However, on a general case, this has typically held true.
- C-BT prices establish both an upper limit on both the ability and willingness to pay by municipal entities. In the early 2000's, the price of C-BT units peaked at nearly $20,000 per acre-foot.
- The increase in demand and price of C-BT units in the early 2000's shows the elasticity of water costs when there is a perceived shortage of future water supplies available. Between the beginning of 1999 and mid-2000, there was a 300 percent increase in the cost of C-BT units. It should be noted that this run on C-BT units occurred in a relatively wet year and prior to drought conditions in 2002. Therefore, this price increase was not caused by immediate fears of impending shortages due to drought conditions (although there was a spike in costs during the 2002-2003 drought), but more likely due to the perception by municipal suppliers that there were limited shares available and costs were increasing to an unknown maximum level.

[3] The costs developed herein are based on costs for water as reported in the publications and by the experts noted in the text. Yield estimates (acre-feet per share) were either provided in the documents above, or taken from South Platte Decision Support System Technical Memorandums on the systems involved. Due to the complexity of the systems involved and yield estimate calculations, the per acre-foot estimates should be considered conceptual level estimates, and should only be used for the purposes described in this document.

- As previously discussed, a value of 25 percent was used as an adjustment factor for large scale transfers. This value was estimated by looking at the temporary adjustment that C-BT shares incurred during drought conditions in 2002, which gives an indication of how markets may react to extreme changes in the perceived supply and/or demand of marketable water. The 2002 condition was determined to be more applicable than the 1999 run on C-BT because all markets within the study area have already adjusted to the 1999 run and are reflected in the base-level prices.

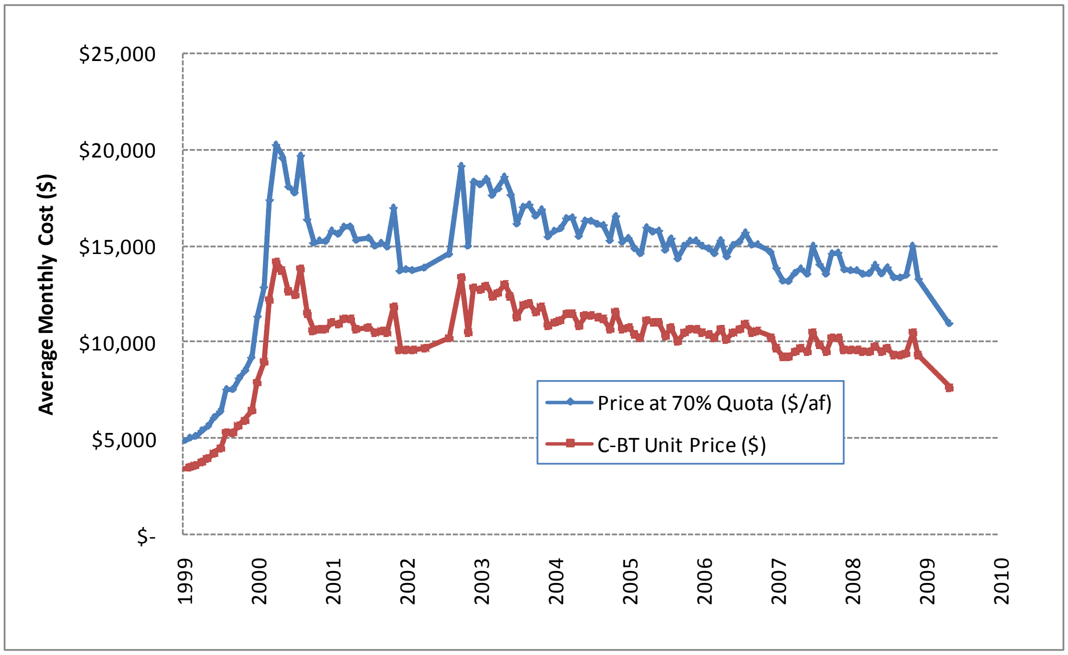


Figure C-1. Historical C-BT Unit Prices

Finally, current cash-in-lieu rates for municipal raw water dedication can also be considered when developing the costs. Nearly all municipalities in the area require developers to provide adequate levels of raw water supply. In many of these municipalities, for smaller developments, there is an option to provide cash-in-lieu of water dedication. In theory, for most municipalities the cash-in-lieu rates provide an indicator of the costs for municipalities to provide this water on the open market. Therefore, within each basin, the general cash-in-lieu rate for sample municipalities is discussed.

<u>Poudre Basin Agricultural Transfers</u>

A summary of transactions for the North Poudre Irrigation Company, Water Supply and Storage Company, Larimer and Weld Irrigation Company, and the New Cache la Poudre Irrigating Company is presented in Figure C-2.

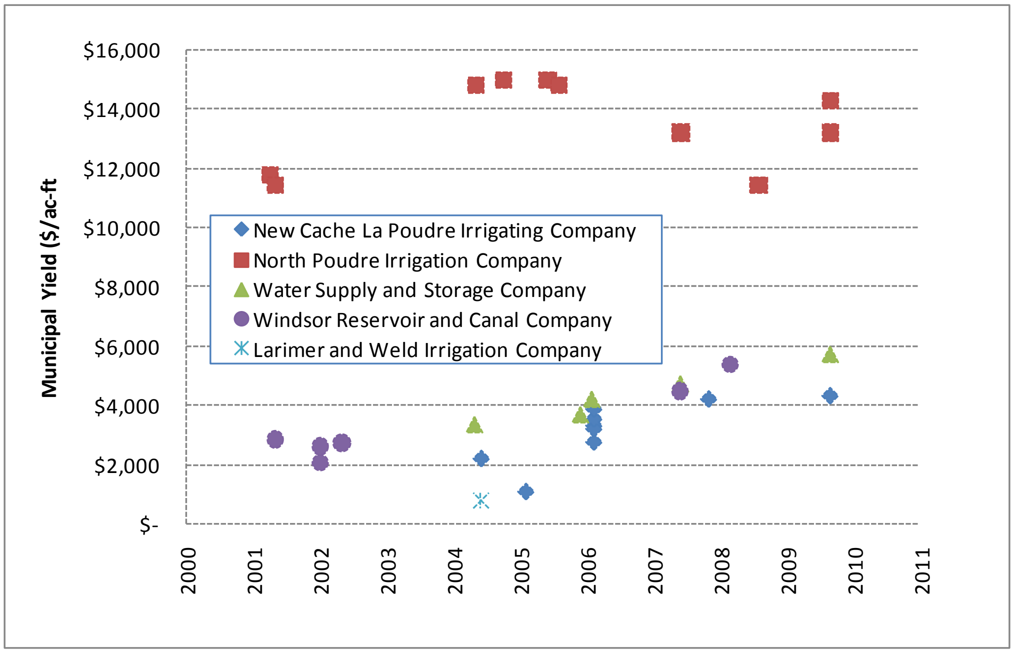


Figure C-2. Poudre Basin Ditch Company Share Transactions

Both the North Poudre Irrigation Company and the Water Supply and Storage Company have active markets for transfers of shares from agricultural to municipal use. The North Poudre Irrigation Company presents a rather unique situation in that shares include both native water and C-BT water, but currently, only C-BT water can be used for municipal use. Native water is leased back to irrigators. Therefore, purchase prices are higher than a typical system and are not comparable to other systems in the area. The Water Supply and Storage Company is more akin to both the New Cache and Larimer and Weld Systems. Thornton is the largest single municipal owner, with a much lesser number of shares owned by other Northern Colorado municipal water suppliers.

New Cache shares have been traded fairly actively within the market. However, all of the recorded transactions have been between irrigators – there have been no recorded transactions to municipal use. Furthermore, because there has not been any New Cache water changed to municipal use, there are no known municipal yields. For purposes of this analysis, it was assumed that municipal yields would be 60 percent of agricultural yields.

Only one transaction of Larimer and Weld shares were recorded in the available data. This transaction occurred several years ago, and was less than $1,000 per acre-foot. However, shares of Windsor Reservoir and Canal Company have been traded fairly regularly, and generally are consistent in per acre-foot price to both Water Supply and Storage Company shares and New Cache shares.

Sample municipal cash-in-lieu rates were obtained for the City of Fort Collins, City of Greeley and Fort Collins-Loveland Water District. Currently, the cash-in-lieu rate is $6,500 for Fort Collins (City of Fort Collins, 2009), $12,300 for Greeley (City of Greeley, 2009) and $12,500 for Fort Collins-Loveland Water District (Fort Collins-Loveland, 2009).

The Water Supply and Storage Company, Windsor Reservoir and Canal Company and New Cache yields provide a reasonable basis for making estimates of the Poudre Basin water supplies considered in the options developed as part of this report. The data shows that prices over the last 3 to 4 years have been in the range of $4,000 to $6,000 per acre-foot. Furthermore, the City of Fort Collins cash-in-lieu rate suggests that local supplies can likely be obtained at the higher end of this range. Based on this information, and increasing the costs by 25 percent to account for the economic effects of large scale purchases, it is estimated that costs for Larimer & Weld and New Cache water will range between $5,000 and $7,500 per acre-foot. It is anticipated that costs in the Poudre Basin will remain lower than the other basins because the systems being considered have lower reliability than South Platte systems, because there is generally more water available in the Poudre basin, and because the water is located a much longer distance to the larger municipal demands in the Denver metro area.

Big Thompson Basin Agricultural Transfers

A summary of transactions for Consolidated Home Supply system, Greeley-Loveland Irrigation Company and the Handy Ditch Company is presented in Figure C-3.

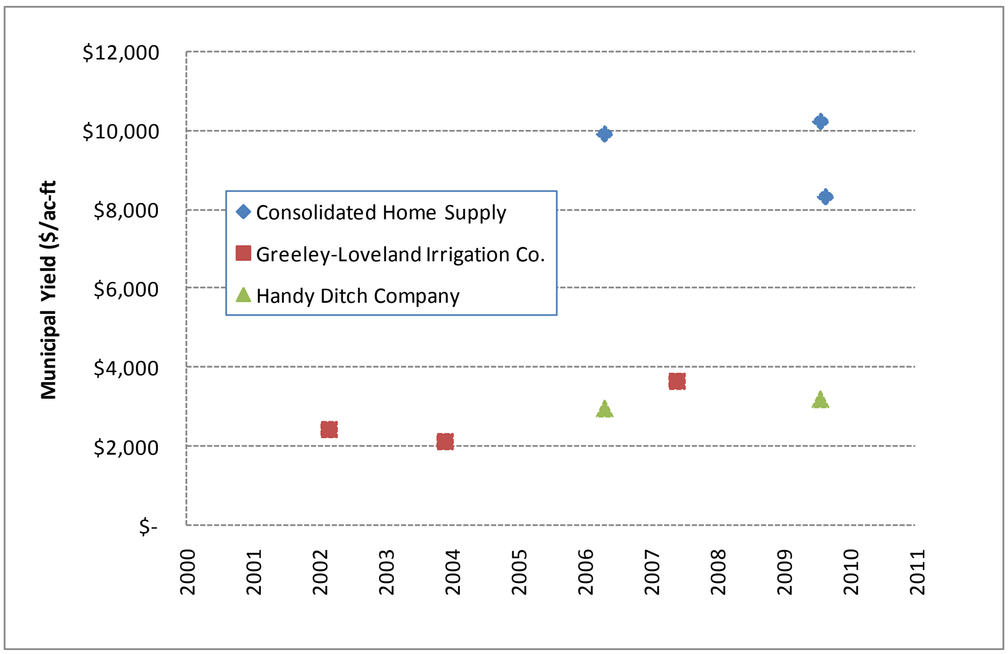


Figure C-3. Big Thompson Basin Ditch Company Share Transactions

All three of these systems have fairly active municipal markets. The City of Greeley is the majority shareholder in the Greeley-Loveland system and has contractual agreements on many more shares that they do not currently own. The Handy Ditch Company has a much lower percentage of its shares in municipal use, but still has a municipal base in those shares owned by the Town of Berthoud. Share prices for both of these systems have varied between $2,000 and $4,000 per acre-foot over the last 10 years.

The Home Supply system has recently become a more actively traded system. The Town of Johnstown completed a change on roughly 1/3 of the system in 2006, and established a ditch wide CU value for its shares in the system. Since that time, share prices have ranged between about $8,000 and $10,000 per acre-foot.

One sample municipal cash-in-lieu price was obtained for the purpose of comparison. The City of Loveland cash-in-lieu price closely follows C-BT unit prices, and was recently adjusted to $9,579 (City of Loveland, 2009).

The primary Big Thompson ditch considered as part of the NISP NAA is the Home Supply system. Because the market for this water is fairly well established, the most recent range of prices, adjusted by approximately 25 percent to account for demand pressure, is used for this analysis. This results in a unit cost of $10,000 to $12,500 for Big Thompson Basin water transfers.

<u>Denver Metro Area Agricultural Transfers</u>

The metro area is generally defined as the area surrounding Denver, and encompasses ditches on the South Platte from Denver to approximately Platteville and associated tributaries within the area. A summary of transactions in this area is shown in Figure C-4. Although this area generally represents a large area and there are many historical and current transactions, there was not a substantial amount of data available regarding these transactions in the documents reviewed as part of this study. In additional the true average annual yield for many of these systems is difficult to determine due to the complexity of agreements.

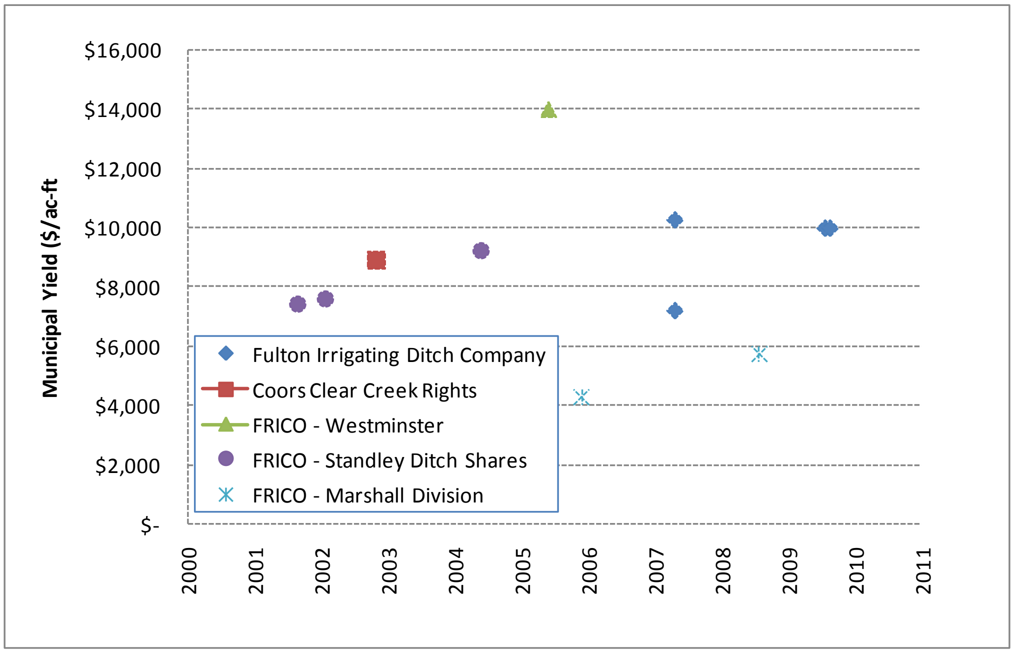


Figure C-4. Metro Area Ditch Company Share Transactions

The most applicable transactions in Figure C-4 to the systems that are being considered as part of the NAA analysis are the Fulton Ditch transactions. All of the Fulton Ditch transactions except one are consistently near $10,000 per acre-foot. The one Fulton Ditch transaction that was near

$7,000 per acre-foot was for irrigation water only, and thus is not directly comparable to NAA municipal uses.

In addition to the Fulton ditch shares, the larger-scale transfer of Farmers Reservoir and Irrigation Company by Westminster provides insight into the elasticity of costs when more substantial portions of shares are purchased. Although the transactions records do not provide much information on the types of shares purchased, the shares are more expensive than the smaller scale transactions of both the Standley Ditch and Marshall Division shares.

Cash-in-lieu fees were investigated for two entities within this study area. The City of Lafayette has a current cash-in-lieu fee of $12,000 per C-BT share (keeping mind that C-BT units have an average quota of approximately 70%) and is tied to the market value fluctuation of C-BT units (Lafayette, 2009). The Town of Erie has a current cash-in-lieu fee of $12,850 (Erie, 2008). These costs are generally higher than communities within the Poudre and Big Thompson basin, likely reflecting the higher costs of purchasing water within the metro area.

Based on the current cost of Fulton Ditch shares, the higher cost of larger-scale transfers established in the Westminster FRICO transfer, and the higher cash-in-lieu costs within this area, the range of costs for water transfers from Metro area ditches (including all ditches investigated on the South Platte) with a 25 percent market adjustment are $12,500 to $15,000.

Maximum Agricultural Transfer from a Single Ditch

As expected, any of the options considered for the NAA would incorporate a large amount of ag transfers. It is unlikely that the full amount of consumptive use water available under a specific ditch could be transferred because current shareholders would be unwilling to sell, or because there would be competition from other shareholders on the systems. Based on historical water transfers from ditches that have a major municipal ownership component, a theoretical maximum limit for ag transfers under a specific ditch was estimated.

Table C-1 presents a summary of municipal and agricultural share ownership for selected ditches within both the South Platte Basin and the Arkansas Basin. Values for the Arkansas Basin are shown to include a comprehensive dataset of ditches within Colorado. In general, the Arkansas Basin ditches are not representative of South Platte ditches because of different economic conditions and willingness to sell, and because the location of these ditches excludes “hobby farmer” or “ranchette” setups that are more prevalent along the front range.

Table C-1. Summary of Current and Maximum Agricultural Transfer from Sample Ditches in South Platte and Arkansas Basins

Ditch/Company	Number of Shares			Percent of Shares	
	Total	M&I	Ag	M&I	Ag
South Platte Basin					
North Poudre Irrigation Company (2005) [(1)]	10,000	6,700	3,300	67%	33%
North Poudre Irrigation Company (Projected Future) [(1)]	10,000	8,500	1,500	85%	15%
Water Supply and Storage Company [(2)]	600	360	240	60%	40%
Greeley-Loveland Irrigation Company					
Fort Collins Southside Ditches [(3)]				40%-70%	
Barnes Ditch [(4)]	1,944	1,319		68%	
Chubbock Ditch [(4)]	1,590	1,252		79%	
Arkansas River Basin					
Colorado Canal Company [(5)]	49,639	44,803	4,836	90%	10%
Rocky Ford Ditch [(6)]	20,000	18,800	1,200	94%	6%
Twin Lakes Reservoir and Canal Company [(5)]	49,589	48,995	594	99%	1%

Sources:

[(1)]BBC Research and Consulting. 2005. Memorandum from Doug Jeavons to Doug Grear, Riverside Technology, Inc., regarding North Poudre Irrigation Company Demand Study. November 4.

[(2)]Percent ownership estimated by Andy Pineda, NCWCD. Total number of shares from SPDSS Task 5 Water Supply and Storage Company memorandum

[(3)]M&I ownership includes changed Fort Collins shares only. From SPDSS Task 5 City of Fort Collins memorandum.

[(4)]M&I ownership includes City of Loveland shares only. From 2005 City of Loveland Raw Water Master Plan.

[(5)]MWH. 2007. Hydrologic Model Documentation Report, Southern Delivery System Environmental Impact Study. Prepared for Bureau of Reclamation. November.

[(6)]Bureau of Reclamation. 2007. Environmental Assessment City of Aurora Proposed Excess Capacity Contracts.

The most direct and studied example of potential maximum levels of ag transfers from large irrigation companies is the North Poudre Irrigation Company. BBC Research prepared a memorandum documenting current and expected future municipal ownership within NPIC (BBC, 2005). The City of Fort Collins and other municipalities began obtaining shares in this system in the 1960's. As of 2005, approximately 67 percent of the shares in the company were owned by municipal water providers. BBC estimated that up to 85 percent of the shares would eventually be municipally owned. The remaining 15 percent was estimated to remain as agricultural shares, owned by full-time farmers who remain in business and by small "ranchettes." It is important to note that the NPIC is a rather unique system, in that C-BT shares are specifically tied to owning NPIC shares, and that there is an active rental market within the system.

There are no other large ditches in the South Platte that either a complete conversion to municipal ownership is complete or where it has been contemplated. However, there are several ditches that are mostly owned by municipal entities and can serve to assist the estimation. For instance, smaller ditches surrounding both Fort Collins and Loveland show that municipal ownership can approach 70 to 80 percent by a single entity.

Based on the information provided above, a two step approach has been taken to estimate the maximum amount of transfers that could be made from a single system. The first step is to reduce the amount of availability in a system by 15 percent to account for the amount of land that will ultimately remain irrigated, either by full-time farmers or as part of smaller ranchettes. The second step is to further reduce availability by a selected percentage to account for shares within a system that would be purchased by entities that are not part of NISP. For ditches with current majority ownership by other municipalities, this percentage will be larger, while for those ditches with little or no current ownership by other municipalities, this percentage will be smaller. Discussions on specific ditches are included in the discussion of the final NAA options.