

**Milton Seaman Reservoir
Enlargement Study**
Greeley, Colorado



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SUBMITTED TO

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Executive Summary

The City of Greeley commissioned a study to evaluate the feasibility of providing additional water storage at the Milton Seaman Reservoir site. Milton Seaman Reservoir is a key component of the City of Greeley's water supply system. Enlarging Seaman Reservoir is consistent with the City's goal of making effective use of existing facilities to satisfy the increasing water demands created by the City's growth.

Milton Seaman Reservoir is located on the North Fork of the Poudre River approximately 1.3 miles upstream from its confluence with the main stem of the Cache la Poudre River, in Larimer County, Colorado, and has a current storage capacity of 5,000 acre-feet (ac-ft). As currently envisioned, water stored in Milton Seaman Reservoir will come from natural flows in the North Fork, with possible supplemental diversions from the Cache la Poudre River above its confluence with the North Fork. The reservoir enlargement will involve various combinations of the following components:

- Milton Seaman Dam with a raised crest to provide increased raw water storage volume.
- A multi-level reservoir outlet to provide improved control of the quality of the water released from the reservoir.
- Water diversion and conveyance facilities from the main stem of the Poudre River to an enlarged Milton Seaman Reservoir to allow more efficient use of water rights in the Poudre basin.

Following are the evaluations of each of these components and their related estimates of construction and operation and maintenance costs.

Milton Seaman Dam with a Raised Crest. The enlargement of Milton Seaman Reservoir can be accomplished through a number of possible options that raise the crest of the existing dam. Relatively small reservoir volume increases (up to approximately 8,500 ac-ft of incremental storage) can be accomplished by constructing a new embankment crest up to 34 feet above the existing crest. The crest of the existing embankment cannot be cost-effectively raised more than 34 feet due to impacts that the footprint of the enlarged embankment would have on the existing outlet works and on the downstream river channel.

Reservoir enlargements for incremental storage volumes greater than 8,500 ac-ft and up to 38,650 ac-ft can be accomplished through construction of a Roller-Compacted Concrete (RCC) dam on the existing site. An RCC dam is viable for the larger reservoir enlargements (i.e., crest raises greater than 34 feet) because the steeper slopes of the upstream and downstream faces of an RCC dam allow a dam footprint that fits efficiently on the existing site. An RCC dam can be constructed to have minimal conflict with the existing outlet

works. The crest of an RCC dam on the existing site could be cost-effectively raised up to 105 feet above the existing dam, resulting in an incremental reservoir storage volume of 38,650 ac-ft. The crest of an RCC dam on the existing site cannot be raised cost-effectively to a height more than 105 feet above the existing crest due to the height of the left abutment of the dam site. A crest raise greater than 105 feet would exceed the height of the left abutment, and the size and configuration of a dam would therefore increase greatly.

Reservoir enlargements for incremental storage volumes greater than 38,650 ac-ft can be accomplished through construction of a RCC dam at a site located approximately 4,500 feet downstream of the existing dam site, just above the confluence of the North Fork with the main stem. This site was previously studied by the Northern Colorado Water Conservancy District for development of storage to serve the northern cities of the Front Range (GEI, 1999). The crest of an RCC dam on this site could be cost-effectively raised to 110 feet above the existing dam, resulting in an incremental reservoir storage volume of 55,000 ac-ft.

Multi-Level Reservoir Outlet. Water quality considerations for the Cache la Poudre River and at the City's Bellvue Water Treatment Plant require that a multi-level outlet should be incorporated into the enlargement of Milton Seaman Reservoir. The multi-level outlet will provide water supply operators with improved control of the quality of reservoir releases. Additionally, if the new or modified multi-level outlet can include improvements that allow maintenance of the outlet without requiring the reservoir to be drained, significant water savings (and corresponding savings in water purchases) can be realized.

The multi-level outlet can be accomplished through various modifications or additions to the reservoir enlargement improvements. If the reservoir is enlarged through an embankment raise, a cost-effective modification to the existing outlet works can be accomplished. If the reservoir is enlarged through construction of a downstream RCC dam, a multi-level outlet can be accomplished through the addition of an intake shaft on the upstream face of the dam. The estimated construction cost for a multi-level outlet ranges from approximately \$2 million for an embankment raise option to approximately \$4 million for an RCC dam raise.

Poudre River Diversion and Conveyance Facilities. The ability to divert water from the main stem of the Poudre River into an enlarged Milton Seaman Reservoir was included as part of this analysis in order to increase the ability of the project to be integrated with other Halligan-Seaman Project participants' existing and future water supplies located on the main stem of the Poudre River. The existing Ft. Collins diversion dam on the Cache la Poudre River can be used to divert main stem flows from the Cache la Poudre River to an enlarged Milton Seaman Reservoir. All diversions from this site will have to be pumped into the reservoir. Three alternative alignments for conveying the diverted water to the reservoir were evaluated. These included two pipeline alignments and one tunneling alignment. The evaluations included a range of diversion rates for various scenarios for enlarging the

reservoir. Feasibility concepts and costs for a pumping station with a related electric power supply were also evaluated.

The investigations and evaluations performed for this study did not identify any technical issues or constraints that would prohibit continued development of the project. Based on available information, the geologic conditions at the site appear favorable for construction of the project features as presently envisioned.

Feasibility-level opinions of probable construction and other project costs have been developed for the various project features described above. Total “project” costs have been developed for each alternative component of the overall project, and include estimates for construction, engineering, administration, permitting, and appropriate design and construction engineering contingencies. Developing the estimated costs for each component allows for the evaluation of a wide range of project configurations, both in size and location of components. Table 1.1 presents a summary of the estimated project costs.

**TABLE ES.1
 PROJECT COST SUMMARY**

Description	Added Storage (ac-ft)	Total Estimated Cost of Dam Raise (\$)	Multi-Level Outlet Project Cost (\$)	Diversion/Conveyance Project Cost (\$)	Total Estimated Project Cost (\$)	Unit Cost of Added Storage (\$ per ac-ft)
18-foot Embankment Raise	3,000	15,300,000	2,000,000		17,300,000	5,767
34-foot Embankment Raise	8,500	25,000,000	2,000,000		27,000,000	3,176
45-foot RCC Dam Raise	11,500	28,200,000 ⁽¹⁾	3,000,000		31,200,000	2,713
95-foot RCC Dam Raise	33,650	41,500,000	4,100,000 ⁽³⁾	6,200,000 ⁽⁵⁾	51,800,000	1,539
105-foot RCC Dam Raise	38,650	43,000,000	4,100,000 ⁽³⁾	6,200,000 ⁽⁵⁾	53,300,000	1,379
110-foot RCC Dam Raise ⁽²⁾	55,000	68,600,000	8,000,000 ⁽⁴⁾	6,200,000 ⁽⁵⁾	82,800,000	1,505

Notes:

1. Includes the cost of provisions for future dam raise.
2. RCC dam site approximately 0.9 miles downstream of Milton Seaman Dam.
3. Estimated cost for the Alternative 1 Multi-Level Outlet (see page 29), rounded up.
4. Updated cost for the Multi-Level Outlet Works for New Seaman Dam (GEI, 1999).
5. Estimated cost for the 30 cfs Pipeline Scenario – East (see page 27), rounded down.

Based on the results of this study, it appears that the Milton Seaman Reservoir Enlargement Project is technically feasible and a potentially cost-effective storage alternative for the City of Greeley.

Section 1 - Introduction

1.1 Background

This report presents the results of the Milton Seaman Dam Enlargement Study performed by GEI Consultants, Inc. (GEI). This study is an update and extension of a previous study prepared by other consultants to the City of Greeley in 1992 (ECI, 1993). This study addresses constructability issues, an incremental damage analysis, water diversion and conveyance for supplemental reservoir supplies, and the feasibility of adding hydropower generation at the site.

Milton Seaman Dam is located in Larimer County, Colorado, in the vicinity of the confluence of the North Fork and the Main Stem of the Cache la Poudre River at the mouth of Poudre Canyon, about 15 miles northwest of Ft. Collins, Colorado. The project location is shown on Figure 1.1. Figure 1.2 shows a general site layout, including the location of Milton Seaman Dam and Reservoir, the proposed Main Stem diversion site, and alternative dam enlargement locations.

Milton Seaman Reservoir is a key component of the City of Greeley's (City) raw water supply system. Situated on the North Fork of the Cache la Poudre River approximately 1.3 miles upstream of the confluence with the main stem of the Cache la Poudre, the reservoir site has been studied as a leading location for development of additional water storage capacity to serve not only the future water needs of Greeley, but also to serve the northern cities of the Front Range. Milton Seaman dam is a jurisdictional, Class I facility under the regulation of the Colorado Office of the State Engineer (SEO).

The City is currently evaluating the enlargement of Milton Seaman Reservoir as part of a regional storage project that includes the enlargement of Halligan Reservoir upstream of Milton Seaman Reservoir on the North Fork of the Cache la Poudre River by the City of Ft. Collins, three water districts, and North Poudre Irrigation Company.

1.2 Purpose

The purpose of this study is to provide the City with the information needed to support their water supply planning and decision-making. The City needs an update of construction costs and construction methods for the reservoir enlargement alternatives that were evaluated in 1992 (ECI, 1993) and a review of potential viable enlargement alternatives not previously covered in the 1992 study. As part of the enlargement evaluation, the City needs a review and evaluation of potential viable options for delivering water from the main stem of the

Cache la Poudre to the various sizes of Milton Seaman Reservoir enlargements being evaluated.

1.3 Authorization

Authorization for this project is provided in an agreement between the City of Greeley and GEI Consultants, Inc. dated October 16, 2003.

1.4 Acknowledgements

We acknowledge the assistance of all who contributed to this study. The project team from the City consisted of:

Todd Williams, P.E.	Water Resources Manager
Sam Boone, P.E.	Water Resource Engineer
Randy Gustafson	Water Supply Superintendent
Stuart Larman, P.E.	Engineering and Planning Manager

The City's project team provided significant direction, coordination, and review input and assistance during the course of the study.

The following personnel from GEI performed the work described in this report:

Curtis A. Thompson, P.E.	Project Manager
James E. Wright, P.G.	Project Geologist
Stephen G. Brown, P.E.	Project Geotechnical Engineer
David J. Priske, P.E.	Project Engineer - Diversion and Conveyance
Korey J. Kadrmas, E.I.T.	Project Engineer - Incremental Damage Analysis
Brian S. Johnson, P.E.	Technical Review
Richard A. Westmore, P.E.	Technical Review

The seismic refraction investigation was performed by MicroGeophysics Corporation under subcontract to GEI. Rock coring and sampling for the borrow area investigation was performed by Spectrum Exploration, Incorporated under subcontract to GEI. Petrographic analysis of rock core samples was performed by Theodore Paster, Ph.D. under subcontract to GEI.

Section 2 – Scope of Work

2.1 General

This study included the following work tasks:

- Task 1 Reevaluate design criteria and aspects of the four alternatives in the 1992 study.
- Task 2 Review and update the constructability and construction costs for the four alternatives in the 1992 study.
- Task 3 Update the original Incremental Damage Analysis (IDA) from the 1992 study.
- Task 4 Identify potential viable enlargement alternatives not previously studied.
- Task 5 Evaluate the potential to phase the addition of storage at the site.
- Task 6 Identify potential viable options and costs for delivering water from the main stem of the Poudre River at a range of delivery capacities.
- Task 7 Perform a feasibility level analysis of the cost/benefit to adding hydropower generation capabilities to the various sizes of reservoir enlargement.

In order to satisfy the City's need for a planning and decision-making tool, this study was conducted using an interactive approach. The project team, including the engineers from the City and GEI, was continuously involved in the assumptions and decisions that were made during the course of the analyses. Six project meetings, including a project kickoff meeting and two report review meetings, were conducted as part of the project. A list and description of each of the primary tasks that were performed as part of this study are included herein as Appendix A.

Existing data was used as much as reasonable, supplemented by new analyses and investigations, as required.

2.2 Field Investigations and Laboratory Analysis

2.2.1 *Field Investigations*

Three field investigations and one laboratory analysis were performed as part of the scope of work. The field investigations included:

1. A geophysical refraction survey that was performed by MicroGeophysics Corporation under subcontract to GEI. The purpose of the refraction study was to measure compressional wave (P-wave) velocities and estimate the top of sound (unweathered) rock along the proposed dam axis for possible RCC dam raises at the existing site. The location of the survey line and the results of the seismic refraction survey are

- described in the report prepared by MicroGeophysics that is included in Appendix B. The survey concluded that the rock foundation at the proposed site is suitable for an RCC dam.
2. Borrow material investigations were performed in order to assess the availability and suitability of dam construction materials in the vicinity of the existing dam. The investigations included a field reconnaissance of potential borrow areas, and drilling of two exploratory holes in the preferred borrow area. The rock core was retrieved from both of the holes that were drilled. The results of the field reconnaissance and rock coring are discussed in Section 3.3 of this report. Drill Hole Logs of the exploratory holes are included in Appendix C.
 3. A field reconnaissance of the Cache la Poudre river channel and floodplain downstream of Milton Seaman Reservoir was performed to assess the suitability of the Incremental Damage Analysis (IDA) included in the previous study of Milton Seaman enlargement (ECI, 1993). The field reconnaissance assessed the existence of structures and/or developments that may have been constructed within the flood plain since the original IDA was performed. The field investigation team included Korey Kadrmas of GEI and Todd Williams, Sam Boone, and Randy Gustafson of the City of Greeley. The results of the field reconnaissance are discussed in Section 3.1 of this report.

2.2.2 Laboratory Analysis

The laboratory analysis included petrographic evaluation of rock core samples that were collected from the borrow area field investigations. The analysis involved preparation of four rock samples (two each from each of the exploratory holes) and microscopic examination of the four samples. The results of the petrographic evaluation are discussed in Section 3.3 of this report. The subconsultant report on petrographic evaluation by Theodore Paster, PhD. is included in Appendix D.

2.3 Work Products

Work products that are required for delivery as part of the scope of work include:

- Progress meetings with City staff to review and evaluate assumptions, analyses, and decisions involved in this study.
- A Final Report that documents all field investigations, data collection, and analyses.
- A presentation of the results of the study to the City of Greeley's Water and Sewer Board.

Section 3 – Engineering Evaluations

3.1 Dam Enlargement Evaluations

3.1.1 General

The Milton Seaman Reservoir site has been studied as a leading location for development of additional water storage capacity to serve not only the future water needs of Greeley, but also to serve the northern cities of the Front Range. The City undertook a feasibility study for the enlargement of Milton Seaman Reservoir in 1992 (ECI, 1993). Additionally, in 1998 the Northern Colorado Water Conservancy District undertook a study on the enlargement of the reservoir as a potential regional water storage facility (GEI, 1999).

3.1.2 Data Collection and Review

GEI collected and reviewed available information from a variety of sources relative to the project area, site geology, design and layout of embankment and roller-compacted concrete (RCC) dams, Cache la Poudre basin hydrology, and construction of hard rock tunnels. These sources included reports, designs, and related documents prepared by or for various organizations and agencies, including the Northern Colorado Water Conservancy District, the U.S. Geological Survey (USGS), the U.S. Bureau of Reclamation (USBR), the City of Greeley, the City of Fort Collins, the planning office of Larimer County, and the Office of the State Engineer of the Department of Natural Resources of Colorado (SEO). A complete listing of these documents is included in Section 8 of this report.

The development of the feasibility designs, layouts, and cost estimates for RCC dam and spillway enlargements of Milton Seaman Reservoir included data from our recently completed work on Standley Lake Dam (RCC spillway) for the Standley Lake Operating Committee; Big Cherry Dam for the Town of Big Stone Gap, Virginia; Black Rock Dam Renovation (RCC spillway) for the Pueblo of Zuni; the New Seaman Dam Feasibility Report for the Northern Colorado Water Conservancy District, and GEI's involvement on the recently-completed final design of Olivenhain Dam (320-foot-high RCC gravity dam). The evaluation of site geology was based on the geophysical refraction survey performed as part of this project and supplemented by the investigations that were completed for the New Seaman Dam Feasibility Report. The hydrologic evaluations involved use of data from the probable maximum flood studies performed for the City of Greeley by Engineering Consultants, Inc. (ECI, 1993) and peak discharge estimates for flood estimates that had been developed for the North Fork of the Cache la Poudre basin studies prepared for the Colorado Water Resources and Power Development Authority. The site topography with 5-foot contour intervals was developed from USGS DEM data. The aerial photo of the site (Figure

1.2) was developed from the USGS 7.5 minute Laporte quad orthophoto as downloaded from the web site www.terraserver.com. The photo was taken on October 4, 1999 and has a resolution of 1 meter.

3.1.3 Site Considerations

The dam site is located on the North Fork of the Cache la Poudre River approximately 5,400 feet upstream of the confluence with the main stem of the Cache la Poudre. The north-south trend of the North Fork of the Cache la Poudre River is controlled structurally by the North Fork Fault. Several other northwest-southeast-trending faults are mapped within the reservoir basin. The North Fork Fault and other faults in the area are not considered to be active.

The dam is located in a relatively steep V-shaped canyon with a relatively narrow ridge that serves as the left abutment of the dam. The dam and spillway are located in pre-Cambrian metamorphic rocks cut by ancient faults. There are no known or mapped landslides in the area of the dam and reservoir, but recent experience with excavations to improve the spillway indicate that large-scale instability can occur in excavations in the vicinity of these old fault features. It has been reported that a fault was discovered in the low saddle in which the spillway is located during excavation for the construction of the labyrinth weir spillway in 1995. The spillway construction was completed with the overexcavation of unsuitable material and the installation of dental concrete to provide a suitable foundation.

3.1.4 Dam Alternatives Analysis

Feasibility designs and layouts of the major features needed to enlarge Milton Seaman Reservoir were developed to achieve the following objectives:

1. Identify and evaluate the dam, outlet works, and spillway facilities needed to satisfy jurisdictional dam safety requirements for an enlarged reservoir.
2. Identify significant design and construction issues that would impact the cost, constructability, and feasibility of the reservoir enlargement.
3. Prepare estimates of project costs for the City to use in comparing the reservoir enlargement options at Milton Seaman Reservoir with other raw water storage options available to the City.

As prescribed by the project scope of work, the feasibility level of investigation for this project was based on review and update of the alternatives in the 1992 study. Additionally, the project included evaluation of the affects of changes to dam safety criteria and regulations, evaluation of constructability issues, and evaluation of potentially viable alternatives that were not previously studied. Therefore, the reservoir enlargement alternatives listed and described on the following page were identified and reviewed.

ALTERNATIVES	VOLUME ADDED	COMMENTS
1992 Study (ECI 1993)		
Centerline Embankment Raises		
18-foot Crest Raise	3,000 acre-feet	See (1) below
30-foot Crest Raise	8,000 acre-feet	See (1) below
50-foot Crest Raise	12,000 acre-feet	See (2) below
100-foot Crest Raise	40,000 acre-feet	See (2) below
This Study		
Resolve Constructability Issues		
Downstream Embankment Raises		
18-foot Crest Raise	3,000 acre-feet	
30-foot Crest Raise	8,000 acre-feet	
34-foot Crest Raise	8,500 acre-feet	See (3) below
Not Previously Studied		
Roller-Compacted Concrete (RCC)		
Dam Raises		
45-foot Crest Raise	11,500 acre-feet	
95-foot Crest Raise	33,560 acre-feet	
105-foot Crest Raise	38,650 acre-feet	
110-foot Crest Raise	55,000 acre-feet	See (4) below

COMMENTS

- (1) These alternatives require construction of a cofferdam within the reservoir or draining of the reservoir to allow embankment construction.
- (2) These alternatives are unacceptable due to conflicts with the existing outlet works and impacts to the channel of the North Fork of the Cache la Poudre River.
- (3) This alternative is considered the maximum feasible downstream embankment raise using the existing embankment. Larger embankment raises create conflicts with the existing outlet works and the channel of the North Fork of the Cache la Poudre River.
- (4) This alternative involves construction of an RCC dam at the “New Seaman” dam site, approximately 0.9 miles downstream of the existing Milton Seaman Reservoir Dam.

The project objectives were used as screening criteria to review and evaluate the alternatives described above. The evaluations included the following key considerations:

Reservoir Operations During Construction - All of the identified enlargement alternatives, except the 115-foot RCC dam at the New Seaman site, will have an impact on reservoir operations during construction. The impacts range from lowering the reservoir for a short time, to complete draining of the reservoir for an extended period. The construction impacts to reservoir operations were quantified by considering either the cost of installing and removing a cofferdam to allow the reservoir to remain in operation during construction, or by

considering the value of replacement water that would have to be purchased to maintain water supply while the reservoir was drained and removed from the water supply operations.

The reservoir operations considerations for centerline embankment crest raise alternatives are significant. Embankment fill operations would require either cofferdam construction or draining of the reservoir. Either of these methods would be expensive (based on an estimated water replacement value of \$1.5 million for draining the reservoir or a minimum estimate of \$2 million for cofferdam construction) and would involve impacts to water quality and the environment. Therefore, alternatives that involve a centerline raise of the dam crest were removed from consideration.

Downstream embankment raises and construction of an RCC dam at the site would involve short-term impacts to reservoir operations that were considered acceptable. It was assumed that reservoir levels would be lowered during foundation excavation and preparation activities for the RCC dam alternatives, and for crest demolition and clearing activities for downstream embankment raise alternatives. Considering the relatively short time frame for the reservoir restrictions and the assumption that the construction activities and reservoir restrictions could be scheduled to have minimal impact on water supply operations, the RCC dam and downstream embankment raise alternatives were considered the preferable alternatives.

Spillway Requirements – The spillway capacity requirements for an enlarged Milton Seaman Reservoir were studied extensively in 1992 (ECI, 1993) as part of an incremental damage assessment (IDA). The objective of the IDA was to determine spillway capacity requirements for a range of reservoir volumes. Since the IDA was performed more than 10 years prior to this study, two tasks were performed to corroborate the validity of the IDA for current conditions. The first task involved use of HEC-RAS computer software to simulate the spillway flow releases as they travel downstream on the Poudre River to the canyon mouth approximately 5 miles downstream. The purpose of this check was to use new computer analysis tools that were developed since the time of the initial analyses to independently verify the results of the initial analyses. The results of the HEC-RAS model for the downstream water surface elevation of the spillway releases were very similar and considered equivalent to the results determined by the previous analyses (IECO, 1980).

The second check involved a field investigation (discussed previously in Section 2.2 of this report) of the Poudre canyon downstream of the Poudre River's confluence with the North Fork. The purpose of this check was to confirm that new development in the canyon and floodplain downstream of the confluence had not adversely impacted the initial evaluations performed for the IDA. The field investigation was aided by the use of several representative topographic cross sections of the Poudre canyon with flood-water depths, and updated mapping of the floodplain. Additionally, GPS equipment was used to check the location of structures.

Various new structures in the project area were identified during the field investigation. The structures were evaluated relative to the possible flood depths determined as part of the IDA, and it was determined that none of the structures were located such that they would change the conclusions of the previous IDA. Therefore, the IDA was considered to be suitable for use in estimating spillway requirements for an enlarged Milton Seaman Reservoir. The results of the IDA that were used in estimating spillway requirements are summarized below.

Milton Seaman Reservoir Results of the Incremental Damage Assessment (IDA) – 1992		
Total Reservoir Volume (Acre-Feet)	Required Spillway Capacity (Cubic Feet per Second)	Spillway Capacity as a Percent of the PMP
8,200	40,200	30 %
20,000	75,500	40 %
30,000	117,900	50 %
43,000	161,900	60 %

The IDA results are not directly applicable to the specific enlargement volumes that were studied as part of this project (i.e., the total reservoir volumes for the IDA are slightly different from those studied herein). However, the IDA results indicate a strong relationship between the reservoir volume and the required spillway capacity. That relationship was used as a guide to estimate the required spillway capacity for each of the alternatives included in this study.

The estimated required spillway capacity for each embankment reservoir enlargement option was compared to the available spillway weir length to evaluate the type of spillway needed. For the embankment dam enlargement options, the only available overflow length was considered to be at the location of the existing spillway. The available weir length for the maximum embankment enlargement that was studied does not provide adequate capacity if the spillway is assumed to be an ogee crest. Therefore, it was assumed that the existing spillway would be demolished and a new labyrinth weir would be constructed at the location of the existing spillway.

For the options that involved an RCC dam, the available spillway length was considered to include portions of the crest of the main dam and portions of the saddle dams that would also need to be constructed. Based on the requirements of the SEO, the required spillway capacity for the RCC dams was considered to be equal to the reservoir inflow produced by the full PMP. The overtopping depth for the RCC dam and the RCC saddle dams (auxiliary spillways) would be uniform based on the simplifying assumption that the crests of the main dam and the saddle dams would be at the same elevation. This assumption should be re-evaluated and modified as necessary during design of a selected option.

Outlet Works Requirements – The primary consideration for the outlet works is to provide a reservoir release capacity equal to or greater than the requirements of the dam safety guidelines of the SEO. The dam safety guidelines require that the outlet works be capable of evacuating the top 5 feet of the reservoir volume within a 5-day period. The reservoir volumes for the enlargement alternatives evaluated in this study result in a maximum required outlet works capacity of approximately 275 cubic feet per second (cfs). The existing outlet works has historically experienced reservoir releases significantly greater than 275 cfs. Therefore, reservoir enlargement alternatives that do not reduce the capacity of the existing outlet works are considered acceptable.

A secondary consideration for the outlet works is to dissipate the energy of the reservoir water being released. The increased water surface elevations of the enlarged reservoir will increase the energy within the reservoir releases. Considering the rock surfaces of the tunnel of the existing outlet works, it was judged that the higher velocities and increased turbulence of reservoir releases would not exceed the capabilities of the rock to dissipate the energy of the water. For new outlet works scenarios that do not use the existing tunnel, energy dissipation must be considered and accommodated in the design.

A more complete discussion of the outlet works scenarios considered in this study is included in Section 3.5 of this Report.

Foundation Conditions – The foundation conditions at the site will be a significant factor in determining the design criteria and the resulting cost-effectiveness of the reservoir enlargement options. Information on the foundation conditions that could be reasonably expected at the site was collected from the previous study for New Seaman Dam (GEI, 1999), from the geophysical refraction survey that is described in Section 2.2, and from the as-built drawing of the foundation profile for the existing Milton Seaman Dam. The primary foundation conditions considered were depth to rock and competency of the rock. The data review concluded that competent bedrock underlies the site and the depth of alluvium and weathered rock over the bedrock is relatively shallow. The existing data indicates that the foundation is capable of reasonably supporting the dam enlargement options considered in this study. Additional foundation investigations should be performed to confirm this conclusion in the next phase of dam enlargement design.

Availability of Materials – All of the reservoir enlargement options will require a large quantity of locally available rock and aggregate materials to cost-effectively construct the raised dam crest and other improvements. The rock and aggregate would be used for embankment fill, for RCC dam materials, and for riprap. Previous studies (ECI, 1992 and GEI 1999) have included cursory considerations of the availability of local materials but did not provide conclusions as to the quality and likely location of the materials. This study included the borrow area field investigations and laboratory analysis described in Section 2.2

of this Report. Based on the site reconnaissance, field sampling, and laboratory analyses that were performed, it appears that the massive bedrock outcropping along the east edge of the reservoir can provide adequate materials, both in quality and quantity, for the reservoir enlargement options evaluated herein.

The petrographic analysis of samples taken from this area indicate that the rock is an adequate, but not ideal, material for RCC aggregate. The analysis identified some trace materials that reduce the overall strength and durability of the rock, but there are no indications that the rock could not be used as an RCC aggregate source. Some processing of the materials quarried from this site is likely to be required to satisfy the material quality criteria established during design. Additional field investigations to more accurately define the extent and quality of the material in the massive bedrock outcropping should be performed as part of the next phase of design efforts. A cost-effective design will consider the quality of the available material and the structural integrity demands of the structure to develop design criteria suitable for the site. As the material quality criteria requirements become more stringent, the quarrying and processing of the material will become more extensive.

Despite the aggregate processing that would be required to use the massive bedrock outcropping as an RCC aggregate source, this site is still considered an attractive source of aggregate. The short and direct haul route from the quarry to the dam site will allow for development of relatively inexpensive RCC materials. This site is also attractive as a source for embankment fill and riprap. The spillway spoil piles and the downstream alluvium could also be developed as cost-effective aggregate sources to supplement the massive bedrock outcropping as needed.

Based on the above considerations, all enlargement options that involved a centerline raise of the embankment were eliminated from further consideration. An option for phased development of the RCC dam enlargements was added to allow evaluation of the cost implications of phased construction. The phased option is discussed in Section 4 of this report.

3.2 Water Diversion and Conveyance

3.2.1 General

The City has, or can obtain, water rights for diversions from the main stem of the Cache la Poudre River above the confluence with the North Fork. Several conveyance alternatives were studied, based on pumping from the existing Ft. Collins Diversion Facility located on the main stem of the Cache La Poudre River above the confluence of the main stem and the North Fork into the enlarged Milton Seaman Reservoir. A discussion of the alternative

alignments, infrastructure, and operating scenarios and costs are presented in the following sections.

3.2.2 Operational Objectives

Several diversion rates were examined as part of the study. All conveyance facilities were initially designed for a peak diversion of up to 55 cubic feet per second (cfs). The 55 cfs peak diversion rate would allow an annual diversion volume of 15,000 ac-ft per year (ac-ft/yr), assuming that the diversions and pumping occur for only 6 months of each year. Annual diversion rates between 10,000 ac-ft/yr and 20,000 ac-ft/yr were also evaluated for conveyance design and to generate operating costs for the study alternatives. Poudre Valley Rural Electric Association (PVREA) charges a use rate associated with real-time electrical demands for the pumping requirements of the system as well as a demand rate continuously applied to the potential peak electrical demand for the entire pump station. Due to this electrical rate structure for industrial users, a much lower and more frequent diversion rate of 21,700 ac-ft/yr (30 cfs) was also evaluated to identify potential operating cost savings.

In addition to being able to deliver water from the main stem of the Poudre River to Milton Seaman Reservoir, the East and Tunnel scenarios would have the capability to deliver water from Milton Seaman Reservoir back to the City of Ft. Collins diversion and water treatment plant. Although the operations of the pipeline are only conceptual, the potential for reverse flow capabilities of the pipeline would give additional redundancy to a regional Halligan-Milton Seaman Reservoir Project.

3.2.3 Pipeline Scenario-West Alternatives

Pipeline Scenario-West conveys water from the existing Ft. Collins diversion structure through a buried pipeline traversing a highpoint ridge and discharging into a tributary drainage channel west of the reservoir as shown on Figure 3.9. The profile for the Pipeline Scenario – West is shown on Figure 3.10. Pumping against the constant uphill gradient simplifies the design of the pipeline. Unfortunately, the elevation differential of over 660 feet increases the operating costs and the complexity of the pump station design compared to the other conveyance alternatives. The major components of this alternative are listed in the following tables for the two peak diversion capacities.

**TABLE 3.1
 PIPELINE SCENARIO-WEST 55 CFS**

Component	Description
Pump Station	(4+1) 1,500 hp ⁽¹⁾
Access Bridge	120-Foot Prefabricated Steel Truss
Intake Structure	Intake Screen and Intake Isolation Valve
Intake Pipe	42-inch Steel Pipe
Conveyance Pipe	36- & 30-inch Steel Pipe
Air Release & Drain Vaults	1 Each
Discharge Structure	Concrete Impact Basin
Electrical Facilities	4160-Medium Voltage

Note:

- (4) 1,500 horsepower pumps with (1) 1,500 horsepower reserve pump.

For this scenario, four vertical turbine pumps each rated for 6,175 gpm at 695 feet of total head and outfitted with 1,500 horsepower motors are required to satisfy peak demands of 39,800 ac-ft/yr. Motors will operate from 4160 medium voltage service.

**TABLE 3.2
 PIPELINE SCENARIO-WEST 30 CFS**

Component	Description
Pump Station	(6+1) 500 hp ⁽¹⁾
Access Bridge	120-Foot Prefabricated Steel Truss
Intake Structure	Intake Screen and Intake Isolation Valve
Intake Pipe	42-inch Steel Pipe
Conveyance Pipe	36- & 30-inch Steel Pipe
Air Release & Drain Vaults	1 Each
Discharge Structure	Concrete Impact Basin
Electrical Facilities	460 Volt / 3 Phase / 60 Hertz

Note:

- (6) 500 horsepower pumps with (1) 500 horsepower reserve pump.

For this scenario, six vertical turbine pumps each rated for 2,245 gpm at 685 feet of total head and outfitted with 500 horsepower motors are required to satisfy peak demands of 21,700 ac-ft/yr. These motors will be operated from 460-volt 3-phase power.

Both diversion scenarios will require a bridge spanning the Cache La Poudre River to access the pump station and facilities, an energy-dissipating structure in order to safely convey releases to the natural drainage channel for the anticipated range of design flows, and similar piping and intake facilities.

Project cost estimates are included in Section 4 of this report.

3.2.4 Pipeline Scenario-East Alternatives

Pipeline Scenario-East conveys water from the existing Ft. Collins diversion and intake structure through a buried pipeline crossing both the main stem and North Fork of the Cache la Poudre. The pipeline discharges into the southeast corner of the existing reservoir embankment. The plan of Pipeline Scenario-East is shown on Figure 3.9. The profile of Pipeline Scenario-East is shown on Figure 3.11. Pumping requirements are significantly reduced for this alternative compared to the West scenario, but the river crossings and increased pipe length adds significant cost to the alternative. In order to quantify the increasing operational costs of pumping during filling of the raised Milton Seaman Dam and Reservoir, assumptions of dry, wet, and average conditions as they influence runoff volumes to the reservoir and within the diversion pool were estimated. The major components for this alternative are shown in the tables below for two peak diversion capacities.

**TABLE 3.3
 PIPELINE SCENARIO-EAST 55 CFS**

Component	Description
Pump Station	(4+1) 500 hp ⁽¹⁾
River Crossings	(1) 350-foot & (1) 450-foot
Intake Structure	Intake Isolation Valve
Intake Pipe	42-inch Steel Pipe
Conveyance Pipe	36-inch Steel Pipe
Air Release & Drain Vaults	3 Each
Reservoir Inlet/Outlet Structure	48-inch Control Gate
Electrical Facilities	460 Volt / 3 Phase / 60 Hertz

Note:

1. (4) 500 horsepower pumps with (1) 500 horsepower reserve pump

For this scenario, four vertical turbine pumps each rated for 6,175 gpm at 242 feet of total head and outfitted with 500 horsepower motors are required to satisfy peak demands of 55 cfs. These motors will be operated from 460-volt 3-phase power.

**TABLE 3.4
 PIPELINE SCENARIO-EAST 30 CFS**

Component	Description
Pump Station	(4+1) 250 hp ⁽¹⁾
River Crossings	(1) 350-foot & (1) 450-foot
Intake Structure	Intake Isolation Valve
Intake Pipe	42-inch Steel Pipe
Conveyance Pipe	36-inch Steel Pipe
Air Release & Drain Vaults	3 Each
Reservoir Inlet/Outlet Structure	48-inch Control Gate
Electrical Facilities	460 Volt / 3 Phase / 60 Hertz

Note:

1. (4) 250 horsepower pumps with (1) 250 horsepower reserve pump.

For this scenario, four vertical turbine pumps each rated for 3,370 gpm at 216 feet of total head and outfitted with 250 horsepower motors are required to satisfy peak demands of 30 cfs.

Both diversion scenarios are similar with the exception of pumping requirements. A control gate located on the reservoir side of the embankment will function to isolate and evacuate the pipeline for scheduled maintenance and control reverse flows from the reservoir to the City of Ft. Collins' diversion on the Poudre River.

Project cost estimates are included in Section 4 of this report.

3.2.5 Tunnel Scenario Alternatives

The tunnel scenario alternative conveys water from the existing Ft. Collins diversion and intake structure through a buried pipeline crossing the main stem of the Cache la Poudre and through a rock tunnel section leading to the upstream face of the existing Milton Seaman Dam near the southwest corner of the reservoir. The plan of Tunnel Scenario is shown on Figure 3.9. The profile of Tunnel Scenario is shown on Figure 3.12. Pumping requirements are significantly reduced for this alternative compared to the West scenario, but the river crossing and tunnel section adds significant cost to this alternative. In order to quantify the increasing operational costs of pumping during filling of the raised Milton Seaman Dam and Reservoir, assumptions of dry, wet, and average conditions as they influence runoff volumes to the reservoir and within the diversion pool were estimated. The major components for this alternative are shown in the tables below for two peak diversion capacities.

**TABLE 3.5
 TUNNEL SCENARIO 55 CFS**

Component	Description
Pump Station	(4+1) 400 hp ⁽¹⁾
River Crossings	(1) 350-foot & (1) 450-foot
Intake Structure	Intake Isolation Valve
Intake Pipe	42-inch Steel Pipe
Conveyance Pipe	36-inch Steel Pipe
Tunnel Section	10' Dia Drill/Blast
Air Release & Drain Vaults	3 Each
Reservoir Inlet/Outlet Structure	120-inch Control Gate
Electrical Facilities	460 Volt / 3 Phase / 60 Hertz

Note:

1. (4) 400 horsepower pumps with (1) 400 horsepower reserve pump.

For this scenario, four vertical turbine pumps each rated for 6,175 gpm at 226 feet of total head and outfitted with 400 horsepower motors are required to satisfy peak demands of 39,800 ac-ft/yr. These motors will be operated from 460-volt 3-phase power.

**TABLE 3.6
TUNNEL SCENARIO 30 CFS**

Component	Description
Pump Station	(4+1) 250 hp ⁽¹⁾
River Crossings	(1) 350-foot & (1) 450-foot
Intake Structure	Intake Isolation Valve
Intake Pipe	42-inch Steel Pipe
Conveyance Pipe	36-inch Steel Pipe
Tunnel Section	10' Dia Drill/Blast
Air Release & Drain Vaults	3 Each
Reservoir Inlet/Outlet Structure	120-inch Control Gate
Electrical Facilities	460 Volt / 3 Phase / 60 Hertz

Note:

1. (4) 250 horsepower pumps with (1) 250 horsepower reserve pump

For this scenario, four vertical turbine pumps each rated for 3,370 gpm at 215 feet of total head and outfitted with 250 horsepower motors are required to satisfy peak demands of 30 cfs.

Both diversion scenarios are similar with exception of the pumping requirements. A control gate located on the reservoir side of the embankment will function to isolate and evacuate the tunnel and pipeline for scheduled maintenance and control reverse flows from the reservoir to the Cache la Poudre River.

Project cost estimates are included in Section 4 of this report.

3.3 Borrow Material Investigations

3.3.1 General

The local availability of borrow material is a critical factor in the construction cost of the reservoir enlargement alternatives. Field reconnaissance and limited drilling explorations were performed to evaluate the availability of local borrow material. Four potential sources were evaluated: 1) outcroppings within the reservoir area, 2) downstream alluvium of the North Fork, 3) spoil piles that resulted from the labyrinth spillway construction, and 4) the massive bedrock outcropping along the east edge of the reservoir (Figure 3.13). A field reconnaissance of these potential sources was performed on July 15, 2003. Spectrum Exploration, Inc. performed exploratory drilling of the massive bedrock outcropping along the east edge of the reservoir in November 2003.

3.3.2 *Outcroppings Within the Reservoir*

The prominent high ridges (Area 1 and Area 2 on Figure 3.13) in the reservoir area appear to have abundant outcrops near the surface. The rock types vary from thinly foliated schist to very coarse-grained granite, the latter being more durable. The topographic high spots generally have a higher percentage of granite and do not weather and erode as readily as the schists. Exploratory drilling would be needed to confirm these areas as borrow sources. Access to the site is extremely limited, and helicopters would be required to mobilize the drilling equipment.

3.3.3 *Downstream Alluvium*

A wide reach of the valley downstream of the dam (Figure 3.13) contains river deposits probably 10 to 50 feet thick. The material is well graded up to approximately 1-foot-diameter and is a mix of rounded and angular pieces. A backhoe test pit program would help characterize the material but may not be able to reach the underlying bedrock, thereby confirming the thickness. Access to the site for an exploratory test pit program will require a significant effort to obtain required permits.

3.3.4 *Spillway Spoil*

A large slide occurred near the spillway and the debris was placed in a dry gulch several hundred feet southeast of the reservoir (Figure 3.13). The material has small grained, weathered particles mixed with hard, fresh, angular boulders 2 feet in diameter. The bedrock exposed near the slide appears slightly weathered to fresh but the material that was hauled to the gulch may contain weaker weathered material. The facility personnel estimate 50,000 cubic yards of material was placed in the waste area.

3.3.5 *Massive Bedrock Outcropping Along the East Reservoir Edge*

The steep slope along the eastern shoreline near the caretaker's residence reflects a near surface, massive outcropping of Precambrian crystalline bedrock. The proximity to the project site, rock type, and volume of readily accessible material make the area a favorable location for project quarries. The rock types are consistent with the previously described outcrop material ranging from thinly foliated schist to very coarse-grained granite. Occasional small shear zones and resultant surface weathering were observed but are not pervasive and can be avoided during the material extraction process.

3.4 Hydropower Evaluations

Hydropower is a renewable source of energy that is often environmentally-friendly when it can be developed in conjunction with an existing dam. The purpose of evaluating

hydropower feasibility as part of this project is to estimate whether hydropower revenues could be used to offset the costs of the reservoir enlargement. One of the key criteria for evaluating possible hydropower operations in conjunction with Milton Seaman Reservoir is the assumption that the primary purpose of reservoir operations is for water supply, and hydropower production would be a secondary benefit of the operations.

The feasibility of hydropower is dependent on several factors, the most important of which are:

- Market value of the produced power
- Annual production rate
- Peak production rate
- Capital cost to develop

Each of these factors can typically have a range of values dependent on the specific characteristics of each hydropower installation. Our evaluation of how each of these factors applies to the conditions of an enlarged Milton Seaman Reservoir is described below.

Market Value of the Produced Power – The market value of produced power can vary significantly depending on the location of the hydropower, the market for electric power, and the regulatory conditions supporting production of renewable energy sources. Experience in the local northern Colorado hydropower market indicates that the contracted market value of hydroelectric power can vary from a low of approximately \$0.01 per kilowatt-hour to a high of almost \$0.07 per kilowatt-hour. These values are weighted-average net values that reflect both a capacity demand payment and a unit production payment. The most significant factors in determining the market value that can be contracted with an energy distributor are the prevailing regulatory environment and the prevailing power availability in the market. Current conditions are depressed for hydropower market value and they do not favor the negotiation and development of an electricity sale agreement at the high end of the range.

Annual Production Rate – The total revenue that can be generated from a hydropower facility is directly related to the flow rate and the available energy (hydraulic pressure) of the water supply. For Milton Seaman Reservoir, the average flow rate and the available energy for hydropower production are unknown because the size of the reservoir enlargement is undetermined and the method of operation of the enlarged facilities is undefined. There is a high probability that the City's water supply operations will be modified significantly if Milton Seaman Reservoir is enlarged, therefore historical flow records are not representative of future water supply operations.

Peak Production Rate – The market value of power that can be generated at a high, short-term production rate is occasionally greater than the average market value of power. Considering that water supply is the primary purpose of the Milton Seaman Reservoir

operations, however, would tend to diminish the potential for developing a significant peak production rate. Water supply operations are typically most efficient when they perform at a relatively steady rate and when changes in operation are gradual rather than rapid. Therefore, the potential for improving hydropower feasibility through peak production rates is limited.

Capital Cost to Develop – The initial capital cost to develop a hydropower project is dependent on the capacity of the facility, the extent of modifications required to develop the hydropower, and the proximity of the facilities to an electric distribution network. The capacity of a facility at Milton Seaman Reservoir cannot be defined until a reservoir volume is selected and a method of operation is determined. The extent of modifications needed for hydropower is dependent on the final configuration of the outlet works. The existing outlet works is a non-pressurized facility that would require significant modification to develop hydropower. The facility's relatively short distance to existing electric power distribution lines is a positive factor.

Based on our evaluation of the hydropower feasibility factors for Milton Seaman Reservoir, the feasibility of hydropower development with an enlarged Milton Seaman Reservoir cannot be quantified. The undefined nature of the size, method of operation, and configuration of the outlet works does not allow a reasonable calculation of potential revenues and estimated costs. By comparing the characteristics of Milton Seaman Reservoir with other developed hydropower facilities in northern Colorado, however, a qualitative assessment of feasibility is implied. The characteristics of Milton Seaman Reservoir, in terms of reservoir height, flow rate, and method of operation compare favorably with other successful hydropower facilities currently operating. Therefore, the feasibility of hydropower development should be evaluated in greater detail when the reservoir volume, method of operation, and configuration of the outlet works have been selected.

3.5 Multi-Level Reservoir Outlet Evaluations

3.5.1 General

The purpose of incorporating a multi-level reservoir outlet into the reservoir enlargement evaluations is to satisfy two of the City's water supply operational objectives:

1. Provide water supply operators with additional flexibility in controlling the quality of reservoir discharges to the Cache la Poudre River. The selective withdrawal of water from various depths in the reservoir will allow the operators to tap the best available quality of the reservoir water as the reservoir stratifies during different seasons of the year. This has the potential to enhance the water quality of the Cache la Poudre River and to improve the efficiency and reliability of water treatment operations at the Bellvue Water Treatment Plant.

2. Allow maintenance of the outlet works flow control equipment without being required to drain the reservoir. Slide gates at the upstream end of the outlet works tunnel control discharges from the existing outlet works. These gates are at the bottom of the reservoir and can only be accessed for maintenance by draining the reservoir. The estimated value of the water in Milton Seaman Reservoir is currently \$1.5 million (5,000 ac-ft at \$300 per ac-ft). This value will increase significantly when the reservoir is enlarged. Therefore, the cost of constructing an outlet works that can be maintained without draining the reservoir will likely be recouped the first time that maintenance is needed for the enlarged reservoir. Considering the age of the existing outlet works, required maintenance is likely to be relatively frequent.

Several criteria were used to evaluate the options available for incorporating a multi-level reservoir outlet into the reservoir enlargement options. The primary criteria for screening options were:

- Accessibility to operators
- Maintenance requirements
- Construction cost
- Adaptability for hydropower

Several scenarios for incorporating the multi-level reservoir outlet into the reservoir enlargement were reviewed and discussed with City staff. Based on these reviews, two options were identified as most suitable for satisfying the evaluation criteria.

3.5.2 Screened Multi-Level Reservoir Outlet Options

Two multi-level reservoir outlet works options were evaluated as part of the enlargement study. With minor differences, both outlet alternatives will function for the RCC and embankment enlargements. Outlet works conduits and control valves were sized to meet SEO requirements for emergency evacuation. The key features common to both reservoir outlet alternatives are:

- Multi-level intakes for water quality management and intake isolation valves for dewatering the downstream outlet works conduit.
- Dry-type intake tower for scheduled inspection and maintenance of intake isolation valves and pipe.
- Pressurized outlet conduit and downstream control valve for regulated releases and optional future hydropower.
- Electrical controls for the remote operation of the intake isolation valves, guard valves, and flow control valves.

A new access road from below the dam to the right abutment and dam crest will be necessary for access to the intake tower for scheduled maintenance and inspection of the intake isolation valves for both alternatives. The key features that make the options unique are described below.

3.5.3 Alternative 1

Alternative 1 incorporates the existing outlet works tunnel and low-level intake for a cost-saving alternative. The existing tunnel will be modified to serve as an access tunnel to the base of a vertical intake shaft that will be constructed near the left abutment. The existing tunnel will be concrete-lined to provide dry and safe access to a new outlet works conduit and control valves, and it will be outfitted with a permanent bulkhead near the existing low-level intake structure. The new outlet works conduit will be constructed within the tunnel and will include a low-level intake isolation valve and control structure.

The new intake shaft will provide access to three new upper reservoir intake isolation valves and a manifold pipe that connects the reservoir intakes. The lower portion of the shaft, below Elevation (El.) 5530, can be excavated into the existing rock of the left abutment. The portion of the intake shaft above El. 5530 would be constructed as a reinforced concrete tower that would abut the RCC dam. The vertical shaft will connect with the existing outlet works tunnel, and will house the outlet works pipe manifold and control valves. One of the new reservoir intakes will be tunneled from the intake shaft to just upstream of the existing embankment at El. 5480. The configuration of the new reservoir intakes and existing low-level intake will allow the existing embankment to remain without affecting the selective withdrawal capabilities of the outlet works. The Alternative 1 outlet works plans and profile are shown on Figures 3.14 and 3.16.

3.5.4 Alternative 2

The intakes for this alternative will be located near the maximum section of the dam alternatives, and their construction will require partial removal of the upstream embankment (existing dam) to allow access to the lower 50 feet of the reservoir pool. An intake tower will be constructed on the upstream face of the new RCC dam, and it will extend from above the dam crest elevation to below the minimum reservoir elevation. Reservoir releases will be conveyed through the multi-level intakes and a connecting outlet works conduit. A flow control building will be located on the right bank of the North Fork, below the dam. Alternative 2 plans and profile are shown on Figures 3.15 and 3.17.

Section 4 – Project Cost Estimates

4.1 General

Opinions of probable construction and project costs have been developed for the various project features described in Section 3 of this report. The costs are presented for the various features individually, with the intent that appropriate combinations of the feature costs will be representative of the total project cost for a possible combination of facility configurations. These estimated costs are based on the feasibility designs presented herein, and are intended primarily for the following purposes:

- To evaluate potential project costs for a range of project configurations and sizes.
- To evaluate the financial feasibility of the project for a range of development sizes and configurations.

All costs are referenced to October 2003.

Construction cost estimates are based on our evaluation of the major construction items appropriate to complete the work. For unit price items, quantity estimates were developed from the feasibility layouts. Lump sum prices are based on qualitative estimates of the work required and the corresponding cost. All costs include allowances for prime contractor and subcontractor overhead and profit. Estimated unit prices and costs for the listed major work items were derived from the following sources: published and non-published bid price data for similar work; R.S. Means Heavy Construction Cost data for 2002; ENR ; GEI’s experience on related construction work; and quotes from local and regional suppliers, manufacturers, and contractors. Price information from projects outside the Ft. Collins region was adjusted using the Means City Cost Index. Price information that was not representative of current cost levels was escalated to October 2003 using ENR’s Construction Cost Index. The ENR Construction Cost Index for October 2003 was taken as 6771.

The estimated construction costs include an allowance for “unlisted items” equal to 10 percent of the listed items. This allowance is intended to cover costs for a variety of items, which would eventually be included in a final bid schedule, but which are not considered major construction items. This allowance would decrease to zero as project development progresses towards final design and construction bidding. The allowance for unlisted items used in this study was derived from an evaluation of other RCC dam projects designed by GEI.

The sum of the listed items plus the unlisted items allowance is defined for this study as the “Base Construction Subtotal” (BCS).

An allowance for the construction contractor's costs for mobilization and bonds and insurance is included as a percentage of the BCS. For the Milton Seaman Dam cost estimates, this allowance was taken as 7.5 percent of the BCS. The cost estimates also include an allowance for construction contingencies. This allowance is essentially the owner's tool for managing the financial risk of a project and, to some degree, is based on the individual owner's risk management approach. At this level of project development, construction contingencies are typically included to allow for project construction cost increases, which could result from a variety of factors including:

- Unforeseen conditions at the site or unexpected project development issues
- Approximations in estimating
- Integration of new and/or more detailed project information or more detailed or rigorous evaluations
- Other unforeseen or unexpected costs

The total allowance for construction contingencies used in the feasibility cost estimates is 20 percent of the BCS, plus the construction contractor's costs for mobilization and bonds and insurance.

The sum of the BCS, mobilization, bonds and insurance, and construction contingencies is defined as the "Direct Construction Subtotal" (DCS).

A "Total Estimated Project Cost" is provided for each project feature, equal to the DCS plus allowances for design engineering, permitting, owner legal and administrative costs, and construction engineering and administration. These cost do not include allowances for purchase of land, acquisition of easements required for project development, or significant environmental mitigation. The City planning and budgeting should include some allowance for these costs. For the feasibility cost estimates, the following allowances were used for these "non-construction" project cost allowances:

- Design Engineering: 6.5 percent of DCS
- Permitting: A lump sum amount of \$2,000,000 for all enlargement alternatives
- Legal and Administrative: 3.0 percent of the DCS
- Construction Engineering and Administration 6.5 percent of DCS

The estimated project costs presented in this report are based on our professional opinion of the cost to develop and construct the project as described in this report. The estimated costs are based on the sources of information described above, and on our knowledge of current construction cost conditions in the locality of the project. Actual project construction and

development costs are affected by a number of factors beyond our control, such as supply and demand for the types of construction required at the time of bidding and in the project vicinity: changes in material supplier costs; changes in labor rates; the competitiveness of contractors and suppliers; changes in applicable regulatory requirements; changes in design standards; and environmental mitigation requirements and other conditions of project permitting. Therefore, conditions and factors that arise as project development proceeds through construction may result in project costs that differ from the estimates documented in this report.

4.2 Reservoir Enlargement

For this study, six alternative sizes of Milton Seaman Reservoir enlargement were evaluated, representing incremental reservoir storage increases as follows:

Description	Added Storage (ac-ft)	Total Estimated Cost of Dam Raise (\$)	Unit Cost of Added Storage (\$ per ac-ft)
18-foot Embankment Raise	3,000	15,300,000	\$5,100
34-foot Embankment Raise	8,500	25,000,000	\$2,941
45-foot RCC Dam Raise	11,500	27,900,000*	\$2,426
95-foot RCC Dam Raise	33,650	41,500,000	\$1,233
105-foot RCC Dam Raise	38,650	43,000,000	1,113
110-foot RCC Dam Raise	55,000	69,000,000	\$1,254

*Includes the cost of provisions for future dam raise

These costs represent only the project costs to construct the dam and spillways as required to satisfy the requirements of the SEO. They do not include the costs for outlet works improvements or for diversion and conveyance facilities.

An additional evaluation and cost estimate were prepared for the option of phased enlargement of Milton Seaman Reservoir. The purpose of phased enlargement is to reduce the short-term capital requirements and risks related to a full-scale enlargement. This evaluation assumed that the 45-foot RCC dam raise would be constructed in Phase 1, and the reservoir would be enlarged with the maximum 105-foot RCC dam raise at a later date as Phase 2. A key assumption in this evaluation is that the foundation treatments required for the full, maximum reservoir enlargement (i.e., Phase 2) would be constructed as part of the Phase 1 reservoir enlargement. These same considerations would also be required for the outlet works and the saddle dams.

The most significant additional costs that result from the phased enlargement are for a second contractor mobilization; additional site clearing, grubbing, and reclamation; treatment of the Phase 1 RCC dam to accept the Phase 2 RCC overlay; and care and diversion of water during the Phase 2 construction. Developing a cost estimate for the Phase 2 construction required

simplifying assumptions related to the condition of the Phase 1 dam after several years of service, the actual design and construction criteria used for the Phase 1 dam, and the reservoir operations during Phase 2 construction. Using the same unit prices that were used for the Phase 1 cost estimates, the Phase 2 construction to develop the maximum RCC dam enlargement at the existing site is estimated to be \$16,600,000. This results in a total Phase 1 and Phase 2 estimated cost of \$44,500,000 for phased enlargement to the maximum RCC dam height. This is equivalent to a \$1,500,000 increase in construction cost for phased development of the reservoir enlargement.

The cost and feasibility of phased enlargement of the reservoir is dependent on several final design factors that include: the method of quarrying in the borrow area, the final design mix for the RCC, and the financial factors of cost of capital and discount rate. It is recommended that the feasibility of phased enlargement be evaluated in greater detail during the next phase of design.

4.3 Diversion and Conveyance

Total diversion project costs were estimated for three alternative scenarios for two different peak diversion capacities. Each alternative is based on pumping from the existing Ft. Collins Diversion Facility located on the main stem of the Cache La Poudre River above the confluence of the main stem and the North Fork. Project cost estimates include construction and pumping costs extended to a 50-year period. Pumping costs for each alternative are based on Poudre Valley REA's rate structure for the average diversion rate, and include a unit price per kilowatt-hour and a monthly demand charge as required. The cost of upgrading Poudre Valley REA's existing 480-volt power supply to the site is included in the construction costs.

The total estimated diversion costs for the conveyance concepts are summarized in Table 4.1 on the following page.

Pumping costs are a significant portion of the total estimated costs for each alternative, and the reliance on pumping for the raw water supply represents a perpetual commitment to the use of a limited resource. Therefore, additional evaluations were performed to more fully assess the suitability of the proposed diversions at the Fort Collins diversion structure. The additional evaluations included a sensitivity analysis of the assumptions used in the pumping cost estimates, and a review of options for eliminating the need for pumping of Poudre River diversions.

**TABLE 4.1
 ESTIMATED DIVERSION COSTS**

	Pumping Costs⁽¹⁾ (\$)	Construction Costs (\$)
Pipeline Scenario - West Alternative		
55 cfs Peak Diversion	32,301,601	8,844,218
30 cfs Peak Diversion	22,861,712	9,019,297
Pipeline Scenario-East Alternative		
55 cfs Peak Diversion	9,691,631	9,043,269
30 cfs Peak Diversion	6,610,557	6,236,621
Tunnel Scenario Alternative		
55 cfs Peak Diversion	8,395,503	10,649,904
30 cfs Peak Diversion	6,567,900	8,254,745

Note:

1. Pumping costs are net present value for future 50-year costs at a 4 percent discount rate. Total annual volume of water pumped is assumed to be 15,000 acre-feet per year. For the 55 cfs Peak Diversion rate, pumping is assumed to occur for approximately 6 months in an average year. For the 30 cfs Peak Diversion Rate, pumping is assumed to occur for approximately 9 months in an average year.

The sensitivity analysis of the assumptions used in the pumping cost estimates focused on the assumed 4 percent discount rate that was used to calculate the Net Present Value of the 50 years of pumping. Also, implicit in the use of the discount rate in the initial calculations was the assumption that energy costs would increase at the same rate as prevailing inflation during the 50-year time frame. Therefore, two variables were included in the sensitivity analysis – (1) the discount rate, and (2) the rate of inflation of energy costs relative to the prevailing rate of inflation. The pumping costs for facilities with an average diversion rate of 30 cfs were used for performing the sensitivity analysis.

The 4 percent discount rate that was assumed for the pumping cost calculations is similar to the discount rate typically used for long-term economic planning for water resource projects. The 4 percent rate is assumed to be representative of economic conditions experienced in the past. However, the City is currently experiencing a discount rate that is significantly below 4 percent, and past experience is not a guarantee of future conditions. Therefore, the sensitivity analysis involved supplemental calculation of the Net Present Value of pumping costs for discount rates of 2 percent and 0 percent.

The assumption that the inflation rate for power costs would be identical to the prevailing rate of inflation for the entire economy is a typical simplifying assumption for economic evaluations. Based on recent conditions, however, the inflation rate of power costs could arguably exceed the prevailing rate of inflation. Therefore, the sensitivity analysis involved supplemental calculation of the Net Present Value of pumping costs with an annual power cost inflation rates that are 2 percent and 3 percent greater than the prevailing rate of inflation.

The results of the sensitivity analysis for the Tunnel Conveyance Scenario are summarized in the following table. The results for the Tunnel Conveyance Scenario are presented as an example because A full tabulation of the pumping costs for all studied conditions (wet year, average year, dry year, 30 cfs, and 55 cfs) and for all three diversion and conveyance scenarios is included in Appendix D.

**SENSITIVITY ANALYSIS
 NET PRESENT VALUE OF PUMPING COSTS –
 TUNNEL CONVEYANCE (30 CFS)**

	Power Inflation 0%	Power Inflation 2%	Power Inflation 3%
Discount Rate = 4%	\$6,567,900	\$11,126,362	\$13,405,593
Discount Rate = 2%	\$9,631,050	\$17,709,856	\$21,749,259
Discount Rate = 0%	\$15,365,095	\$30,730,190	\$38,412,738

One method of evaluating the results of the pumping cost sensitivity analysis is to consider the discount rate and power inflation combinations where the pumping costs become equal to or greater than the incremental cost of constructing diversion and conveyance facilities that do not require pumping (gravity conveyance). Cost estimates for gravity conveyance facilities specific to Milton Seaman Reservoir have not been developed, but they have been studied previously as part of other regional water storage evaluations.

A previous study by the Northern Colorado Water Conservancy District (GEI 1999) evaluated the feasibility of upstream diversions on the Poudre that could be delivered to the New Seaman Reservoir site by gravity (no pumping). The study involved feasibility evaluation of the costs for tunnel construction to allow gravity conveyance of Poudre River diversions to an enlarged Milton Seaman Reservoir. The conceptual tunnel alignment would have a total length of approximately 22,500 feet, and the tunnel profile would be developed to provide gravity flow to an enlarged Milton Seaman Reservoir. The estimated cost of the tunnel, based on September 1998 dollars, was \$29,300,000. Updating that estimate to October 2003 dollars results in an estimated cost of \$33,250,000.

4.4 Reservoir Outlet

Total reservoir outlet works costs were estimated for two alternative scenarios as described in subsection 3.5 of this Report. Alternative 1 involves modification of the existing outlet works, and Alternative 2 involves construction of a new, separate outlet works. Each alternative allows for selective withdrawal for water quality management and scheduled maintenance and inspection of outlet works appurtenances without lowering the reservoir below normal pool elevation. Total estimated project costs for the constructed alternatives are:

- Alternative 1 \$4,079,695
- Alternative 2 \$5,319,929

For comparison purposes, an estimated construction cost was prepared for the multi-level outlet works that was included as part of the New Seaman Dam study (GEI, 1999). The conceptual design of the outlet works for New Seaman Dam included a reinforced concrete intake riser, six selective withdrawal control gates, and two outlet works conduits with stream release outlet valves. Based on the construction quantities from the New Seaman Dam study and updated construction unit prices, the estimated construction cost for the multi-level outlet for the maximum RCC dam raise is \$8,000,000.

Section 5 – Conclusions

5.1 Enlargement of Milton Seaman Reservoir

The nature and scope of dam improvements that are needed for the enlargement of Milton Seaman Reservoir are dependent on the amount of additional storage that is desired. The topography of the abutments and the downstream channel at the existing dam are significant constraints that dictate the type and size of dam improvements that can be reasonably implemented. The following table summarizes the maximum crest raise and corresponding increase in storage that can be achieved for each type and configuration of dam that were studied on the site of the existing dam.

**TABLE 5.1
 SUMMARY OF RESERVOIR ENLARGEMENT OPTIONS**

Description	Storage – Total/Added (Acre-Feet)	Normal Water Surface El.	Crest Raise ⁽³⁾ (Feet)	Crest Elevation
Downstream Embankment Raise ⁽¹⁾	11,000/6,000	5522	34	5534
Maximum RCC Dam Raise with new abutment ⁽¹⁾	43,650/38,650	5605	105	5605
Downstream RCC Dam ⁽²⁾	60,000/55,000	5610	110	5610

Notes:

1. Dam crest raise on the site of the existing dam.
2. New dam on the site of the New Seaman Dam as proposed by Northern Colorado Water Conservancy District.
3. Height of dam crest raise above existing top of parapet wall.

5.2 Incremental Damage Analysis (IDA)

The incremental damage analyses (IDA) performed previously by others (ECI, 1993 and IECO, 1980) were reviewed for their suitability in analyzing spillway requirements for each of the reservoir enlargement options included in this study. For the enlargement options that involve an embankment dam, the review included the use of computer software to determine water surface elevations in the Cache la Poudre River downstream of Milton Seaman Dam. A field reconnaissance of the river channel and flood plain downstream of Milton Seaman Reservoir was performed to confirm the lack of hazards that would be inundated by the incremental flooding that would result from the potential breaching of the embankment dam. For the enlargement options that involve an RCC dam, the review included discussions with

representatives from the SEO and determination of spillway requirements to pass the probable maximum flood (PMF).

Our review concluded that the previously prepared IDAs for possible Milton Seaman Reservoir embankment enlargements are currently suitable for the embankment enlargements included in this report. Interpolation of the results from the previous IDAs indicates that a spillway capacity of approximately 60,000 cfs, corresponding to approximately 35 percent of the PMP, is required for the maximum embankment enlargement (incremental storage of 8,500 ac-ft) that was studied. This magnitude of spillway capacity can be achieved on the existing site through the demolition of the existing labyrinth weir spillway and the construction of a new labyrinth weir with a raised crest elevation and an increased weir length.

Representatives of the SEO were consulted for interpretation of the IDA regulations as they apply to RCC dams. Mr. Mark Haynes, P.E. and Senior Water Resource Engineer within the Dam Safety Branch of the SEO explained that concrete gravity dams (which includes RCC dams) are only considered acceptable if they are able to pass the PMF without experiencing a breach. Since the dam is assumed to not develop a breach due to hydrologic conditions, an incremental damage analysis therefore does not apply to RCC dams. As long as the dam and spillways are designed and maintained with the integrity and stability required to pass the PMF, incremental damages caused by a hydrologic breach of the dam are not possible.

The results of the previous hydrologic analysis for Milton Seaman Reservoir watershed (ECI, 1993) indicate that an overtopping capacity of approximately 274,00 cfs is required to pass the PMF through Milton Seaman Reservoir. As an example, this magnitude of overtopping capacity can be accomplished by designing the dam and spillways for an overtopping depth of approximately 13 feet and a tailwater depth of approximately 43 feet for the 105-foot RCC dam raise option.

5.3 Multi-Level Reservoir Outlet Evaluations

The purpose of including a multi-level reservoir outlet with the reservoir enlargement improvements is to:

- Improve the ability of water supply operators to control the water quality of reservoir discharges to the Cache la Poudre River.
- Eliminate the requirement for draining the reservoir to perform maintenance on the outlet works gates.

Based on these objectives, the following evaluation criteria were used to select reservoir outlet alternatives for further study:

- Construction Cost
- Accessibility
- Maintenance
- Adaptability to Hydropower

Two multi-level reservoir outlet options were developed that satisfy these criteria; however, both options also have drawbacks associated with them. For RCC dam options, access to the proposed intake tower of the outlet works for maintenance and inspection of the valves cannot occur while the reservoir is overtopping the dam. However, changes to reservoir release rates and water quality control measures could continue through remote actuation of the reservoir intakes and flow control valves. Maintenance and inspection tasks would be scheduled for periods when the dam is not being overtopped.

Option 1, which incorporates the existing intake structure and outlet tunnel, has the disadvantages of difficult mobilization of new equipment to the site for construction of the shaft and tunnel work and increased risk associated with tunneling. A concern with Option 2 is the environmental and cost concerns of breaching the existing embankment during construction. Even with successful removal of the upstream embankment, regardless of cost, there is an increased potential for collection of sediment near the low intake.

5.4 Diversion and Conveyance

Three alternative pipe/tunnel configurations for various flow rates were studied for diverting water from the Cache la Poudre below Milton Seaman Dam and conveying it into Milton Seaman Reservoir. Regardless of the pipe/tunnel configuration selected, there are significant savings for diversion rates with reduced peak capacity due primarily to the reduced pumping power costs associated with the reduced peak capacity. Some of the criteria used to evaluate the alternatives included:

- Construction Cost
- Accessibility
- Capability for Two-Way Flow (Delivery to and from City of Ft. Collins Diversion on the main stem of the Poudre River)
- Maintenance
- Pumping Costs
- Future Capacity Increases

Pipeline Alternative–West is the least desirable alternative as the pumping costs associated with the anticipated diversion rates are many times greater than the other options for a 50-year life cycle. In addition, the proposed pipeline alignment is not a direct route and the alternative does not allow for two-way flow into and out of the reservoir. The total estimated

project capital costs for this alternative are less than the other alternatives. Although for the lower capacity, the pumping requirements increase in an attempt to move from the 4160 electrical service to the 480-volt service.

Pipeline Alternative-East is the more attractive of the two pipelines. The total estimated project costs are comparable to the other pipeline because pipe costs increase and pump station costs decrease. In addition, it is assumed that this alternative may take advantage of the existing Ft. Collins diversion facilities located on the Cache la Poudre. The location of the pipeline terminal facilities will allow for flow from the reservoir to the City of Ft. Collins Diversion on the Poudre River with the pump station by-pass facilities on-line. Some of the disadvantages of this alternative include the two river crossings, the additional cut and cover pipe located within U.S. Forest Service lands, and the inconvenience and increased costs associated with upgrading the capacity for future needs.

The Tunnel Alternative is very attractive considering all the criteria used to evaluate the diversion and conveyance alternatives. This alternative is the most direct alignment studied. Operating costs associated with pumping for either capacity is the least expensive of all alternatives studied. The length of cut and cover pipe is significantly less, reducing areas of site disturbance and permitting. Options for increasing capacity are improved within the large diameter tunnel. This alternative has the capability for two-way flows to and from the reservoir. The total project cost for this alternative is greater than the East alternative. This is primarily due to the cost of tunneling from the river to the reservoir, the transition from pipe to tunnel, and the inlet/outlet structure.

5.5 Hydropower Feasibility

The feasibility of hydropower development at an enlarged Milton Seaman Reservoir cannot be quantitatively assessed due to the large number of undefined factors (e.g., reservoir size, method of operation, market value of power). However, a qualitative feasibility evaluation, through comparison of Milton Seaman Reservoir characteristics with the characteristics of other successful hydropower facilities in northern Colorado, indicates that there is a potential for hydropower development.

Section 6 – Recommendations

The recommendations resulting from this study are as follows:

- Reservoir Enlargement: The type of reservoir and dam enlargement that should be pursued for Milton Seaman Reservoir is dependent on the total reservoir storage volume that is desired. The next step in the planning process for Milton Seaman Reservoir should involve definition of the quantity and timing of additional storage that is needed by project participants. Based on the desired reservoir storage volume, it is recommended that reservoir enlargement should be pursued as follows:
 - Reservoir enlargement through a downstream embankment raise should be used if the total incremental storage volume desired is less than or equal to approximately 8,500 ac-ft.
 - An RCC raise of the dam should be used if the total incremental storage volume desired is greater than 8,500 ac-ft.
 - If an RCC raise of the dam is selected, a financing and phasing evaluation of construction costs should be performed to determine the suitability of phased enlargement of the reservoir. Additional investigations of the foundation bedrock at the proposed dam axis and at the saddle dams should also be performed to refine the RCC dam construction cost estimates.
- Diversion and Conveyance: Two configurations of diversion and conveyance facilities were selected as potential methods to convey water between the main stem of the Cache la Poudre River and the enlarged Milton Seaman Reservoir:
 1. The Pipeline Scenario – East
 2. The Tunnel Scenario

The Tunnel Scenario is slightly more expensive than the Pipeline Scenario – East, but the Tunnel Scenario has the advantages of access to more reservoir capacity for two-way flow, less environmental impacts for construction, and potential for additional capacity in the future at much lower cost. The next step in the planning process for the diversion and conveyance facilities should involve evaluation of the advantages of the Tunnel Scenario as they compare to its slightly higher cost than the Pipeline Scenario – East. If any of the three advantages of the Tunnel Scenario are considered significant, then the Tunnel Scenario is an attractive option.

- Incremental Damage Analyses: The Incremental Damage Analyses (IDA) that were performed as part of previous studies continue to be valid as a measure of the

spillway capacity that would be required for various reservoir enlargement scenarios. The City should continue to monitor development in the Cache la Poudre channel downstream of Milton Seaman Reservoir. The advantages of an RCC dam raise could become more significant if additional development occurs in or near the current flood channel.

- Multi-Level Reservoir Outlet: Two multi-level reservoir outlet alternatives were conceptually designed and evaluated as potential methods to allow selective withdrawal of water from various depths in Milton Seaman Reservoir. Both alternatives include dry-shaft configurations to allow maintenance of the outlet works flow control equipment without draining the reservoir. Alternative 1 has the lowest estimated construction cost, but it also includes significant construction cost uncertainty related to rock excavation for a vertical intake shaft that connects to the existing outlet works tunnel, and modified use of the existing tunnel. Alternative 2 has a higher estimated construction cost, but there is a greater confidence level in the cost estimate because it does not require significant rock excavation or modifications to existing facilities. The next step in the planning process for the multi-level reservoir outlet should be further investigation and evaluation of the constructability of the Alternative 1 components: the proposed vertical intake shaft and the modifications to the existing outlet works tunnel. The evaluation should include geologic mapping and testing of the outlet works tunnel, and sampling and testing of rock cores from the site of the proposed vertical intake shaft.
- Hydropower Development: The feasibility of hydropower development should be evaluated after the size and operations of the proposed reservoir enlargement have been determined. If hydropower development is considered to have economic benefits, then a full feasibility evaluation can be performed. The full feasibility evaluation should consider the costs and impacts of permitting and jurisdictional oversight based on the assumption that the primary purpose of the water facility operations is for water supply and the hydroelectric power generation would be a secondary benefit.

Section 7 – Limitations

This report has been prepared for the exclusive use of the City, for the specific application to the enlargement of Milton Seaman Reservoir. GEI has endeavored to comply with generally accepted engineering practice common to the local area.

The engineering evaluations, analyses, designs, and estimation of probable construction and project costs are based on GEI's understanding of the project location, project features, and available information referenced in this report. The analyses contained in this report are based on limited seismic refraction survey data and without benefit of subsurface drilling and testing. The methods used indicate subsurface conditions only at the specific locations where investigations were performed, only at the time they were performed, and only to the depths investigated. Data cannot be relied on to accurately reflect subsurface conditions outside the range of testing.

This report includes opinions of the probable construction and project costs. GEI's opinions of probable costs have been based solely upon its experience or knowledge of similar work. GEI's opinions of probable cost are influenced by: 1) various assumptions regarding the actual conditions that will be encountered on site; 2) the means, methods, sequences, equipment, safety programs, et al., that contractors may employ; 3) the cost and extent of labor, equipment, and materials that contractors may employ; 4) contractors' methods for determining prices and market conditions at the time; 5) impacts to project costs and development which may occur as a result of permitting and NEPA compliance issues; and 6) a variety of other factors over which GEI has no control.

Section 8 – References

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