THE MUDDY RIVER
RATIONALE FOR PROPOSED REVISIONS TO SELECT WATER QUALITY REGULATIONS AND WATER QUALITY CRITERIA
(NAC 445A.210 – NAC 445A.211)

Bureau of Water Quality Planning
May 2008

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Executive Summary

Introduction

This document discusses proposed changes to the water quality standards for the Muddy River. The proposed changes involve modifying the water quality regulations and revising select water quality criteria. Detailed discussion of the proposed changes including supporting information and documentation is presented in the rationale document. Revisions are summarized below.

Reaches

It is proposed to separate the Muddy River into an upper reach, a middle reach, and a lower reach. The current reach from the source springs downstream to Glendale Bridge would be maintained as the upper reach. The current lower section of the river below Glendale Bridge would be divided into two segments: a middle reach from Glendale Bridge to Wells Siding diversion; and a lower reach from Wells Siding diversion to Lake Mead.

The proposed middle reach coincides with the current management of the Muddy River flows and subsequent use of the river water. At Wells Siding, natural river flows are diverted for subsequent agricultural use in the lower Moapa Valley. Revising the lower reach of the Muddy River to extend from the Wells Siding diversion to Lake Mead establishes a reach specific to the stretch of the river that primarily conveys return flows/tail water from irrigation uses in the lower Moapa Valley.

Additional language will be added to regulatory description of the upper reach of the Muddy River to indicate that the portion of the river that flows through the Moapa Band

of Paiutes tribal land is exempt from the State of Nevada's water quality standards and regulations. As a sovereign nation, the Moapa Band of Paiutes is responsible for regulating the water quality of the river within the boundaries of their land.

Beneficial Uses

The beneficial use of recreation involving contact with the water is proposed for all reaches of the Muddy River. Assigning this particular use is consistent with the goals of the Clean Water Act. All existing beneficial uses on the Muddy River will be retained.

Water Quality Criteria

Color

The existing narrative color criteria on the upper reach of the Muddy River will be replaced with a criteria value of ≤ 75 PCU. This numeric criteria has been recommended by the United States Environmental Protection Agency (EPA) to protect municipal and domestic supply beneficial use.

The upper reach is the only section of the river that has been designated as a potential source for municipal or domestic supply. The existing narrative color criteria which restrict any increases to a defined limit above natural conditions will be maintained for the middle and lower reaches of the Muddy River.

Escherichia coli (E. coli)

E. coli bacteria water quality criteria that currently exist on the Muddy River (≤ 630 per 100 ml) will be replaced with more restrictive criteria values to support the inclusion of water contact recreation as a beneficial use for the entire river. The proposed *E. coli* water quality criteria are an annual geometric mean of ≤ 126 per 100 ml and a single sample value of ≤ 410 per 100 ml, per EPA recommendations for protection of human health during water contact recreational activities. These values are similar to the *E. coli* criteria that have been adopted for other Nevada surface waterbodies with a beneficial use of recreation involving contact with the water.

Temperature

It is proposed to revise the current seasonal temperature criteria of ≤ 21 °C (November-June) and ≤ 32 °C (July-October). The proposed revisions are based on the habitat temperature requirements of the endemic native fish species that occupy various sections of the Muddy River, and also capture the range of temperature fluctuations that occur naturally. Proposed temperature water quality criteria are shown below.

Muddy River	Proposed Criteria
Upper Reach	
Source Springs to Warm Springs Road	19 °C ≤ T ≤ 32 °C
Warm Springs Road to Glendale Bridge	15 °C ≤ T ≤ 30 °C
Middle Reach	
Glendale Bridge to Wells Siding diversion	15 °C ≤ T ≤ 30 °C
Lower Reach	
Wells Siding diversion to Lake Mead	T ≤ 32 °C

The existing beneficial use temperature limit of $\Delta T \leq 2$ °C and anti-degradation limit of $\Delta T = 0$ °C will be included with the proposed temperature water quality criteria for each reach.

Fluoride

Under the Clean Water Act, States can develop waterbody specific criteria, rather than rely on EPA recommended national criteria, as long as the developed criteria protect and/or support the beneficial uses of the waterbody. It is proposed to adopt fluoride water quality criteria based on the fluoride levels that have naturally been present in the Muddy River. For the upper and middle reaches, a fluoride criteria of 2.6 mg/l is proposed which reflects the elevated natural background fluoride concentrations in the headwaters and upper portion of the river. For the lower reach, a fluoride water quality criteria of 3.6 mg/l is proposed. This value is based on the measured fluoride levels in the lower Muddy River and accounts for reduced volumes of flow and evaporative concentration effects associated with normal agricultural practices.

Supporting information and data are presented in the rationale document for development of the proposed fluoride water quality criteria values and to demonstrate that the

proposed numerical values are protective of the beneficial uses associated with the Muddy River.

Boron

A waterbody-specific boron irrigation water quality criteria of 2.0 mg/l is proposed for the lower Muddy River reach. This criteria is reflective of the historical boron levels that have been measured in the lower Muddy River. Supporting information is presented in the rationale document to show that the proposed boron threshold value is protective of the irrigational uses of water from the lower river channel.

Bowman Reservoir

Bowman Reservoir is a Class C water and the beneficial uses and water quality criteria in NAC 445A.126 apply to this waterbody. It is proposed to make Bowman Reservoir a designated waterbody thereby creating a table of water quality standards specific to Bowman Reservoir. The existing water quality criteria contained in NAC 445A.126 would be incorporated into the table of water quality standards for the reservoir with the following additions:

- The proposed fluoride water quality criteria of 2.6 mg/l for the upper and middle reaches of the Muddy River is also proposed for Bowman Reservoir. At the Wells Siding diversion, which is the lower end of the middle reach, Muddy River water is diverted to Bowman Reservoir for subsequent agricultural use in the lower Moapa Valley.

- Due to its association with the Muddy River, Bowman Reservoir is also considered a water of the Colorado River Basin. As such, the Colorado River Salinity Standards (total dissolved solids) specified in NAC 445A.143 which are assigned to the Muddy River would also be applicable to Bowman Reservoir.

Summary

A detailed discussion of the Muddy River basin including historical and current management strategies for use of the river water is presented in the rationale document. Muddy River water chemistry monitoring data is presented and compared to the proposed water quality criteria revisions to evaluate attainment. Supporting information and data from the literature is presented to document that the proposed site-specific fluoride and boron water quality criteria which were developed based on natural conditions will protect the beneficial uses associated with the Muddy River. Available water chemistry data from the Overton Arm of Lake Mead is used to evaluate, on a cursory basis, the impacts of high fluoride and boron levels in the Muddy River entering the lake.

1.0 Introduction

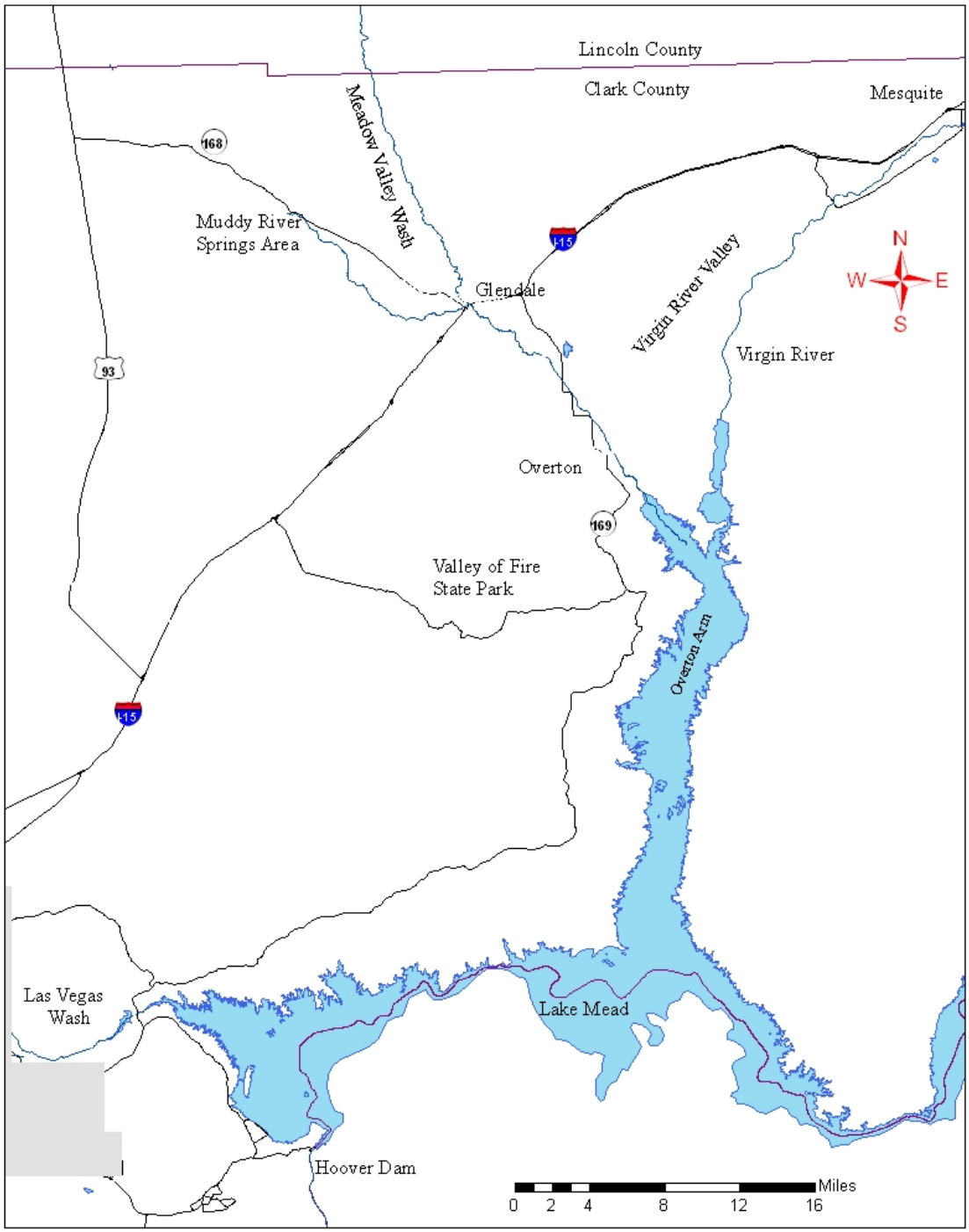
Under Section 303 of the Clean Water Act, States and authorized tribes have the responsibility for routinely reviewing and, as appropriate, modifying surface water quality standards that protect the designated uses of a water body and provide a basis for controlling discharges or releases of pollutants. The Nevada Division of Environmental Protection, Bureau of Water Quality Planning (NDEP-BWQP) is proposing revisions to the surface water quality standards for the Muddy River. The water quality standards for the Muddy River were last reviewed and amended, in part, in 1985.

During the public review process of proposed regulation changes, stakeholders and entities whom may be affected by the proposed changes are afforded the opportunity to address their individual concerns and participate in the regulatory adoption process. Proposed changes to the water quality standards and Nevada Administrative Code (NAC) are not effective until acted upon by the State Environmental Commission (SEC) and approved by the Nevada Legislative Commission and USEPA. Any new or revised standards for the Muddy River would not be incorporated as permit effluent limits until the proposed standards are incorporated into the NAC regulations. The NDEP Administrator can require existing effluent permit limits to be updated when the standard limits become effective; however, past practice has been to adjust the effluent limits at the time of permit renewal.

2.0 Background

The Muddy River is located in northeastern Clark County, Nevada, about 60 miles northeast of Las Vegas, and is within the Colorado River Hydrographic Basin (see Figure 1). The river originates from several thermal springs which surface in an area known as Warm Springs situated about 6 miles northwest of Moapa, Nevada. From its origin, the Muddy River flows in an easterly to southeasterly direction through the Moapa Valley. Along its course, the river passes through the towns of Moapa, Glendale,

Figure 1. Geographic Location of Muddy River, Northeast Clark County



Logandale, and Overton. The river is diverted for agricultural use in the upper and lower Moapa Valley. The terminus of the Muddy River is the Overton Arm of Lake Mead; flows at this point being primarily irrigation tail water. Historically, the Muddy flowed into the Virgin River; a short distance upstream of the confluence of the Virgin and Colorado River. When Hoover Dam was constructed, the lower length of the Muddy River and its confluence with the Virgin River was subsequently submerged by Lake Mead. The length of the Muddy River from its source to its confluence with Lake Mead is approximately 32 miles or greater (depending on the water level in Lake Mead). An overview of the Muddy River corridor is shown in Figure 2.

Precipitation occasionally produces some runoff in the Muddy River basin, but at such intermittent intervals that its contribution to Muddy River flows is negligible. Meadow Valley Wash, which originates near Pioche, Nevada, flows generally south about 100 miles to its junction with the Muddy near Glendale (see Figure 2). Due to diversions in the upper portion of Meadow Valley Wash and channel losses by transpiration and deep percolation, very little of the natural flows in Meadow Valley Wash reach the Muddy River at Glendale. Although the discharge from the headwater springs in the Warm Springs area is nearly constant, by the time the Muddy River flows reach Lake Mead, a significant portion of the flow has been lost to diversions, evaporation, and transpiration.

As shown in Figure 3, from its origin in the Warm Springs area, the Muddy River flows through the Moapa Paiute Tribal Reservation and through the Nevada Power Company (NPC) Reid Gardner power generating station property. Upon leaving the NPC property, the Muddy River continues on an easterly course flowing under Interstate (I-15) near Glendale.

Figure 2. Overview of Muddy River Corridor

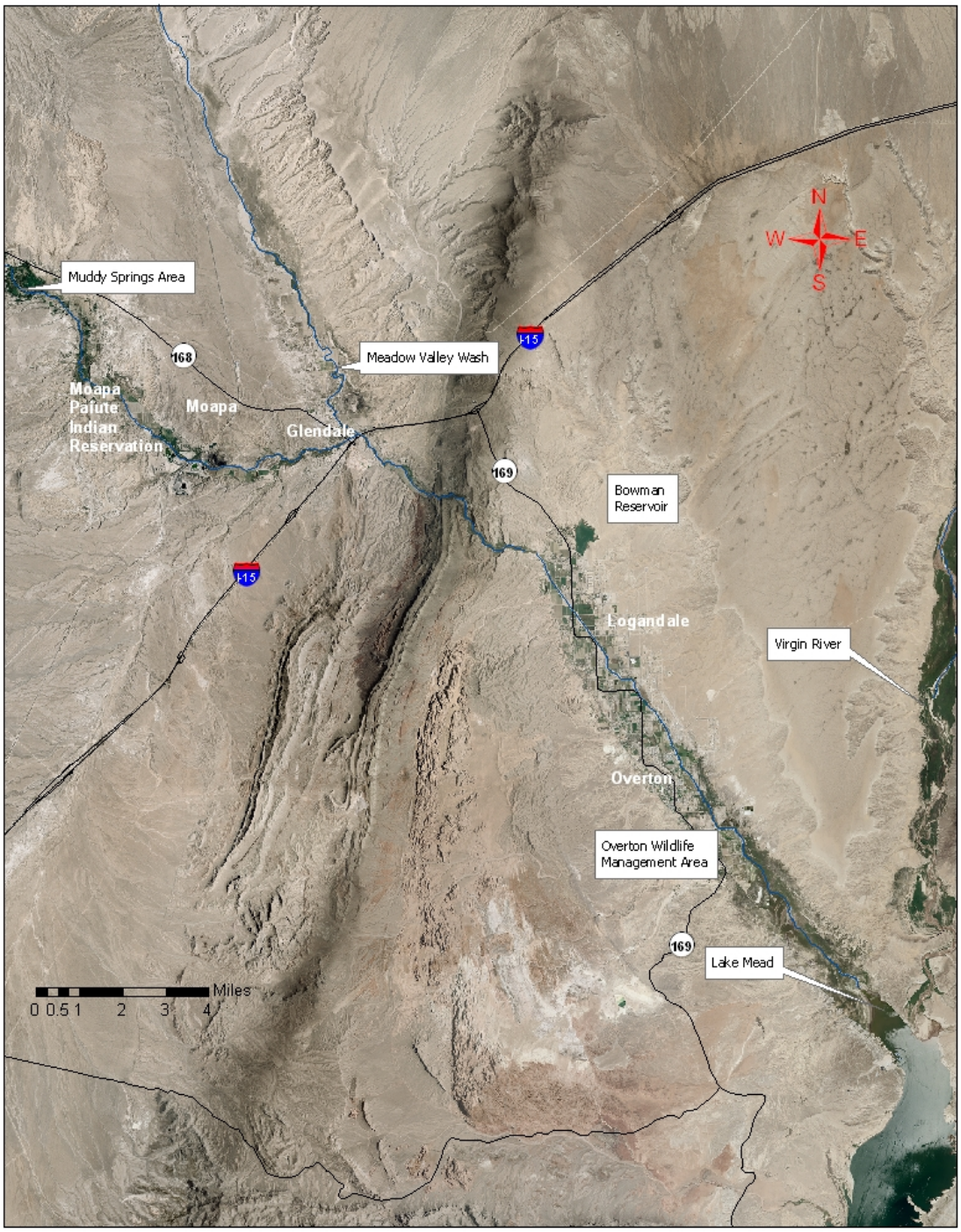
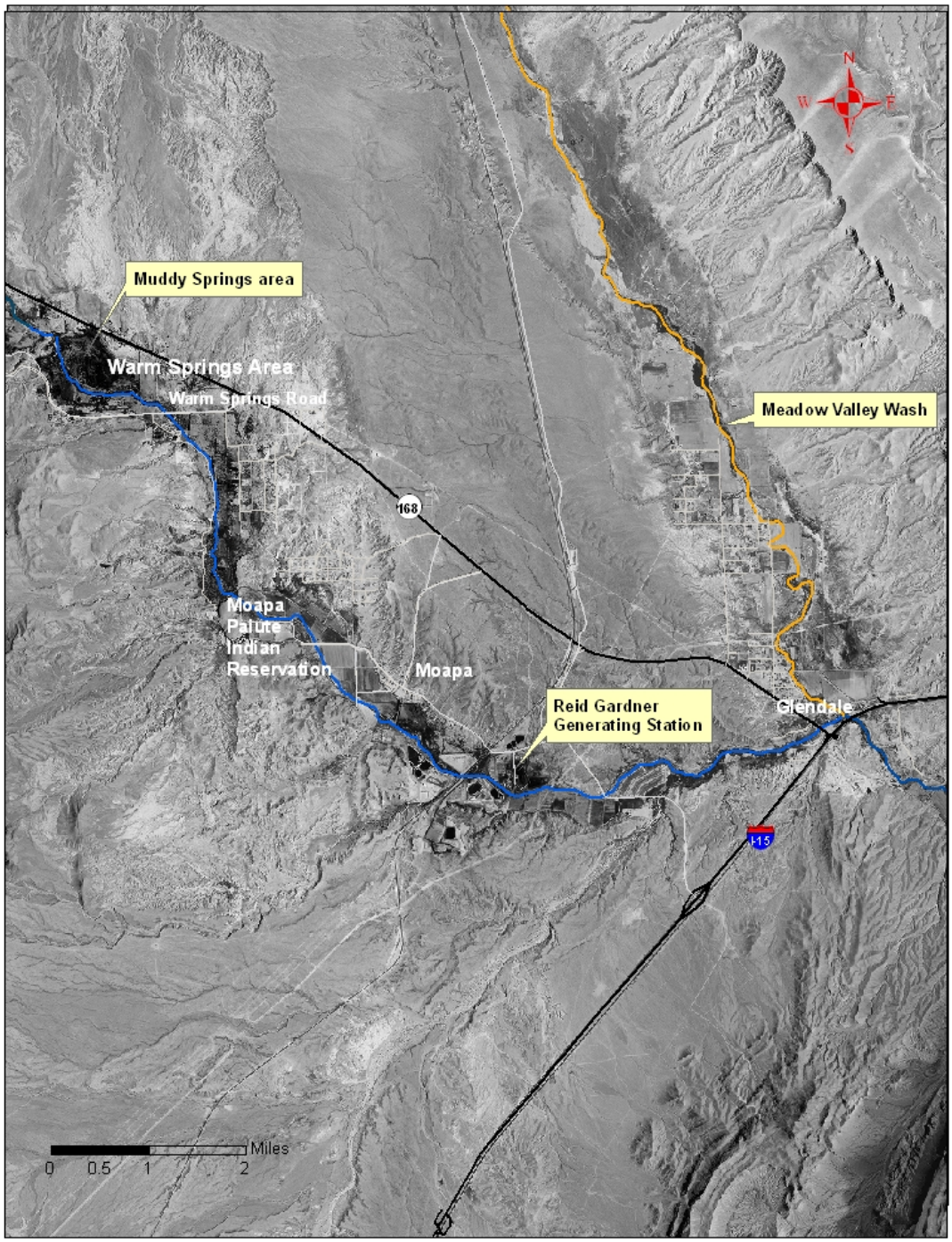


Figure 3. Upper Muddy River Corridor.

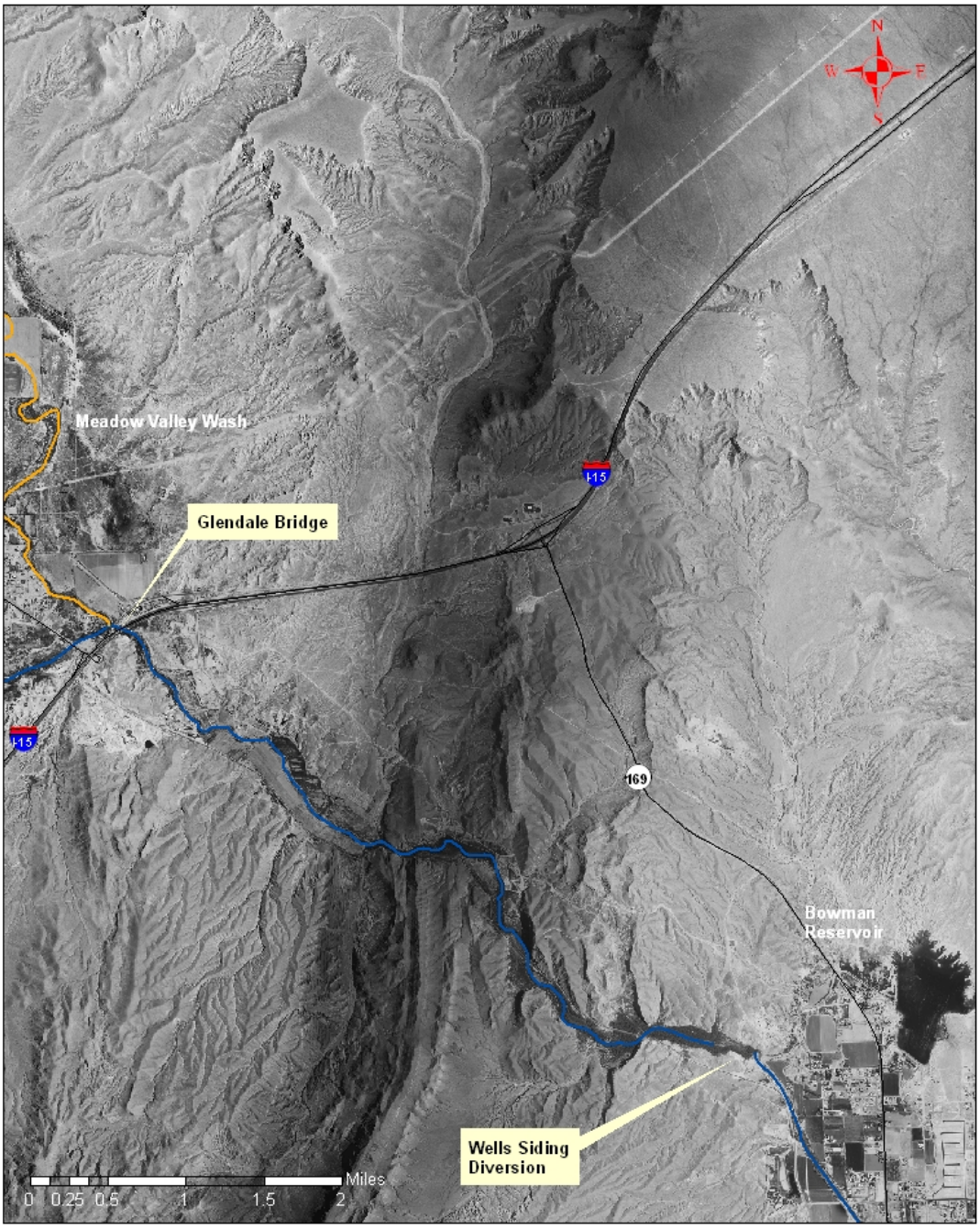


Downstream of Glendale, the river passes through what is known as the "Narrows" where the walls of the valley converge forming a narrow canyon. This canyon area serves as a physical demarcation that divides the Moapa Valley into an upper and a lower section, and segregates the river into upper and lower designations. Below the Narrows, the Muddy River flows are diverted at the Wells Siding diversion into the lower Moapa Valley canal system and/or Bowman Reservoir. An overview of the Muddy River corridor from below Glendale to the Wells Siding diversion is shown in Figure 4.

The Muddy River Decree of 1920 allocated all water in the lower Moapa Valley to the Muddy Valley Irrigation Company (MVIC). Full flow of the river during irrigation season is allocated to agricultural use. Irrigation water is delivered to downstream users in the lower Moapa Valley through a canal system with associated laterals that extend down the valley on both sides of the Muddy River channel. Water is supplied to the canal system either directly by the Wells Siding diversion or indirectly from Bowman Reservoir. Irrigated lands in the upper Moapa Valley are supplied water by individual direct diversions from the Muddy River and by wells.

Bowman Reservoir was constructed by the Forest Service with Civilian Conservation Corp labor and was completed in 1936. Its main purpose was for flood control and its original capacity was about 1,000 acre-feet. In 1967-1968, the Muddy Valley Irrigation Company (MVIC) reconstructed the Bowman dam and increased the reservoir capacity to 4,000 acre-feet. Muddy River water runs into the reservoir by gravity flow from the Wells Siding-Bowman Reservoir canal until the water surface in the reservoir reaches the water elevation in the canal; thereafter, water is pumped from the canal into the reservoir (Bureau of Reclamation 1971).

Figure 4. Middle Muddy River Corridor



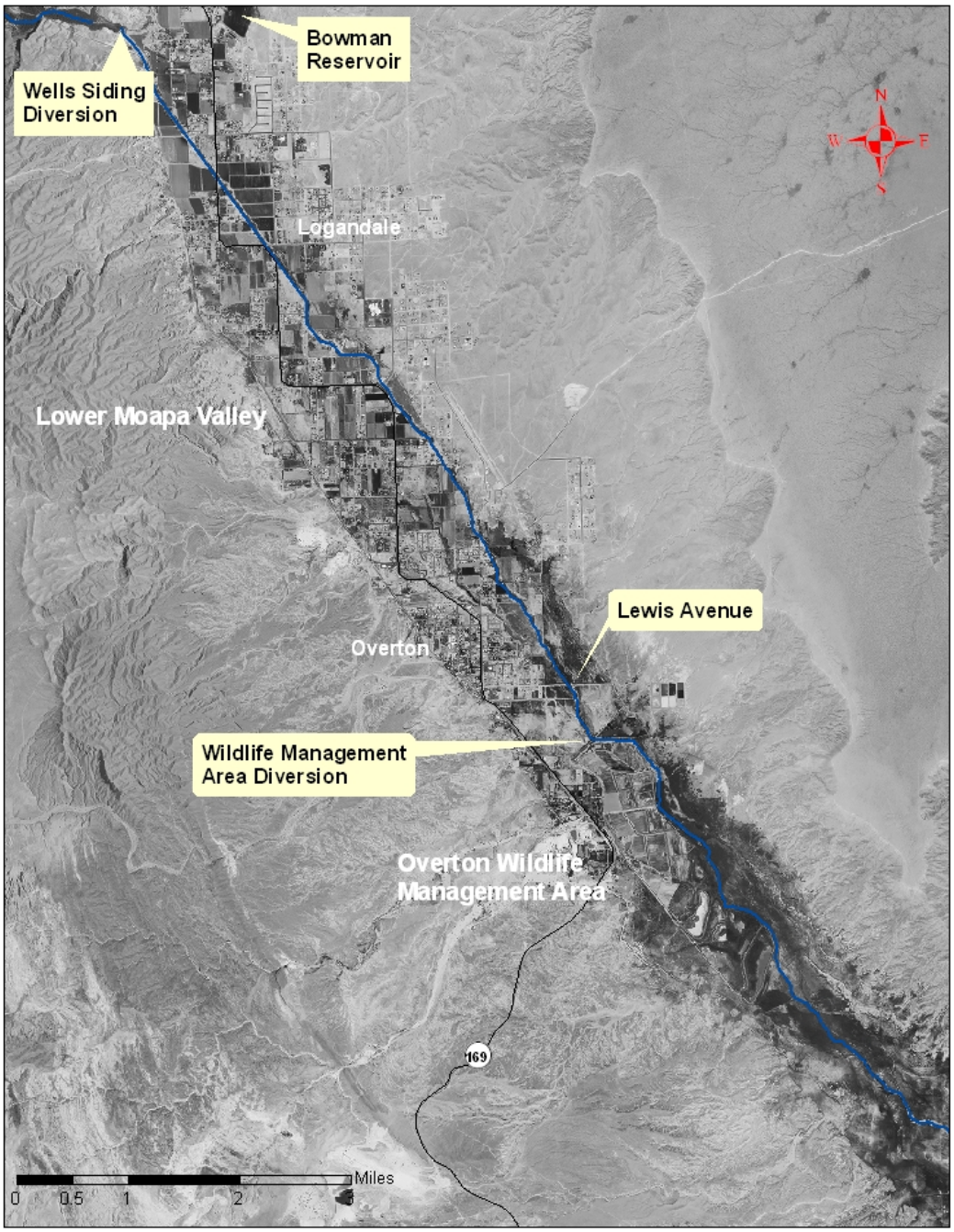
An overview of the lower Muddy River channel is shown in Figure 5. Return flow to the river channel below irrigation uses in the lower Moapa Valley is placed to beneficial use in the operation of the Overton Wildlife Management Area (per the Muddy River Decree of 1920). Below the Wells Siding diversion, the only withdrawal of water from the lower stretch of the river is at the Overton Wildlife Management Area. The Nevada Division of Wildlife (NDOW) operates a diversion structure to acquire return flows from the lower Muddy for filling ponds and irrigating crops which provide habitat, forage, shelter, and escape cover for migratory waterfowl and wildlife. The Wildlife Management Area also receives water via the MVIC canal system for use on the project area.

The readily available supply of water from the Muddy River for irrigation was a significant reason for the development of agricultural lands in the Moapa Valley. Historically, three types of farms were present in the Moapa Valley; dairy farms, row crop farms, and beef cattle farms, or a combination of the three. Today, alfalfa and sudan grass are the primary crops grown during the summer with a rotation to oats and barley for pasture during the winter.

Drainage problems have always plagued the lower Moapa Valley. When the valley was settled (late 1800s/early 1900s), a major portion of the valley floor consisted of wet meadows and tule swamps through which the Muddy River meandered. The water table remained at or near the surface during most of the year. The swampy condition existed until a channel was made through the valley. A channel was started by flood waters in 1910; further deepening of the channel resulted from later floods and by farmers channelizing the stream for drainage. When the river was confined to a definite channel, the lighter soils in the valley floor soon became tillable, and as the channel became deeper, more land was drained and placed under cultivation (Bureau of Reclamation 1951). The original river channel was changed from the west side of the valley to the east side due to land on the west side being more suitable to farming. As time and floods have passed, the river channel through the lower valley has increased in size to current conditions. The Wells Siding diversion Dam and Bowman Reservoir were not

constructed until 1935/1936 by the Civilian Conservation Corps. The capacity of Bowman Reservoir was increased in 1967 by the MVIC (Bureau of Reclamation 1962).

Figure 5. Lower Muddy River Corridor



Today, the principal use of the Muddy River is still for agricultural irrigation. Surface water users from upstream to downstream include the Muddy Valley Irrigation Company, Nevada Power Company, Moapa Paiute Indian Reservation, and Nevada Division of Wildlife. Although the Muddy River is not used as a drinking water supply source, the Moapa Valley Water District has constructed collection systems at two of the surface springs which are in the headwaters area of the Muddy River (Warm Springs Area). Water from these springs is combined with groundwater from wells in the vicinity of the springs to supply potable water to the Moapa Valley.

3.0 Water Quality Regulations

The Nevada water quality regulations which have been adopted to protect surface water bodies in the State are part of the Nevada Administrative Code (NAC) Chapter 445A. These regulations specify the beneficial uses of the water bodies and define the water quality criteria necessary to protect or support the uses to be made of the water. The water quality regulations, in certain cases, also contain anti-degradation requirements to maintain existing higher water quality conditions.

Beneficial uses must be consistent with the goal of the Clean Water Act section 101(a)(2), which provides for the "protection and propagation of fish, shellfish, and wildlife" and "recreation in and on the water" (the "fishable/swimmable" uses). Beneficial use classification must also consider the use and value of water for public water supplies, agriculture (irrigation and livestock watering) and industrial processes.

In the water quality regulations, the major river systems are generally divided into reaches or segments which characterize the physical attributes of the river and watershed, different land uses and different beneficial uses. Each reach associated with a river system has a specific set of water quality standards that are applicable to the entire length

of the reach. The water quality standards are the specific levels of water quality desired to support and protect the identified beneficial uses. A monitoring point is associated with each reach and is usually a downstream location within the reach where water chemistry samples are generally collected, and where an evaluation is made of whether the water quality standards are being attained.

The current water quality regulations specific to the Muddy River are listed below:

NAC 445A.174 – Beneficial Uses for Muddy River below Glendale Bridge;
NAC 445A.209 – Beneficial Uses for Muddy River above Glendale Bridge;
NAC 445A.210 – Standards of Water Quality for Muddy River at Glendale Bridge;
NAC 445A.211 – Standards of Water Quality for Muddy River at Overton

Additionally, the narrative criteria contained in NAC 445A.121 and the water quality criteria contained in NAC 445A.144 are applicable to the Muddy River.

4.0 Summary of Proposed Changes to Water Quality Regulations and Standards

The following changes are proposed to the Muddy River water quality regulations. The corresponding section(s) of this document that address each of the proposed changes are also shown.

- Separate the Muddy River into three reaches. The proposed reaches are (1) source springs downstream to Glendale Bridge;
  (2) Glendale Bridge downstream to Wells Siding diversion; and
  (3) Wells Siding diversion downstream to Lake Mead [Section 5.0].

- Revise the regulatory language describing the Muddy River reaches and waterbodies in the Muddy River basin [Section 5.0].

- Revise the nomenclature of the upper Muddy River reach from its origin downstream to the Glendale Bridge to exclude the stretch of the river that flows through the Moapa Band of Paiutes tribal reservation from State of Nevada water quality regulations [Section 5.0].

- Add "recreation involving contact with the water" as a beneficial use for the Muddy River and amend the *E.coli* water quality criteria to protect this beneficial use [Sections 6.1 and 9.0].

- Revise the color water quality criteria from a narrative statement to a numerical value that protects municipal and domestic supply beneficial use on the upper reach [Section 8.0].

- Revise the temperature water quality criteria for the Muddy River [Section 11.0].

- Revised the fluoride water quality criteria standard for the upper and middle reaches, including Bowman Reservoir to reflect the elevated natural background concentrations of fluoride measured in the headwaters and upper portion of the river [Section 12.3].

- Develop site-specific fluoride and boron water quality standards for the lowermost segment of the Muddy River. These site-specific standards are based on the inherent nature of the water comprising the lower Muddy, and the corresponding point of diversion and use of this water [Section 13.1 and Section 15.1].

5.0 Muddy River Reaches

Proposed Revisions to the Muddy River Reaches and Reach Designations

It is proposed to segregate the Muddy River into three segments: (1) the existing upper reach from the source springs to the Glendale Bridge (see Figure 3); (2) a middle reach from the Glendale Bridge downstream to the Wells Siding diversion (see Figure 4); and (3) a lower reach from the Wells Siding diversion downstream to Lake Mead (see Figure 5). The Glendale Bridge on the north side of Interstate-15 (I-15) will be maintained as the control point for the upper reach from the source of the river to Glendale. The control point for the middle reach will be at the Wells Siding diversion. The control point for the lower reach would technically be the mouth of the river at Lake Mead. However, due to limited access to this section of the river, a monitoring point for the lower most section of the river will be downstream of the Overton Wildlife Management Area diversion dam.

It is proposed to revise the nomenclature of how the Muddy River reaches are described. The reach descriptions would be from an upstream designation to a downstream location.

Additional language is included in the regulatory language describing the existing upper reach of the Muddy River to indicate that the length of the river contained within the exterior borders of the Moapa Band of Paiutes tribal reservation is exempt from State water quality regulations.

Rationale for Proposed Revisions to the Muddy River Reaches and Reach Designations

Creating a middle reach for the Muddy River that extends from the Glendale Bridge down to the Wells Siding diversion coincides with the current management of the Muddy River flows and subsequent use of the river water. This new reach is logical as it would cover natural river flows (below Glendale) prior to diversion to the MVIC canal system and/or Bowman Reservoir for subsequent irrigation use in the lower Moapa Valley.

Revising the lower reach of the Muddy River to extend from the Wells Siding diversion down to Lake Mead covers the section of the river below the MVIC point of diversion. This revision establishes a reach specific to the stretch of river which has been extensively altered by agricultural activities and which primarily conveys return flows/tail water from irrigation uses in the lower Moapa Valley.

The proposed revisions to the reach descriptions for the Muddy River change the description to be from an upstream designation to a downstream location rather than vice versa. These proposed changes are consistent with the reach description nomenclature that has been adopted for other rivers and streams in the Nevada water quality regulations.

The State of Nevada water quality regulations are not applicable to the stretch of the Muddy River that traverses the Moapa Band of Paiutes Moapa Reservation. As a sovereign nation, the Moapa Band of Paiutes is responsible for regulating the water quality of the river within the boundaries of their land. Additional language will be included in the upper Muddy River water quality regulation to reflect that the State water quality standards do not apply to the stretch of the Muddy River within the exterior borders of the Moapa Band of Paiutes reservation.

6.0 Beneficial Uses

The existing and proposed beneficial uses for the Muddy River are listed below:

Table 1. Beneficial Uses for the Muddy River.

BENEFICIAL USES	Source Springs to Glendale Bridge (Upper Reach)	Glendale Bridge to Wells Siding diversion (Middle Reach)	Wells Siding diversion to Lake Mead (Lower Reach)
Aquatic Life (warm water)	Existing	Existing	Existing
Wildlife	Existing	Existing	Existing
Recreation – water contact	***Proposed***	***Proposed***	***Proposed***
Recreation–nonwtr contact	Existing	Existing	Existing
Irrigation	Existing	Existing	Existing
Livestock Watering	Existing	Existing	Existing
Municipal/Domestic Supply	Existing	Not Designated	Not Designated
Industrial Supply	Existing	Existing	Existing

The beneficial uses which currently exist on the lower section of the Muddy River would be retained as the existing beneficial uses for the middle and lower reaches. The Muddy River near its origin has been designated as a potential source for municipal or domestic supply; consequently, this beneficial use is assigned only to the upper reach.

6.1.a Proposed Revisions to the Beneficial Uses for the Muddy River

It is proposed to include "recreation involving contact with the water" as a beneficial use for all sections of the Muddy River.

6.1.b Rationale for Proposed Revision to the Beneficial Uses for the Muddy River

To be consistent with the "fishable/swimmable" goal of the Clean Water Act, water contact recreation is proposed as a beneficial use on all sections of the Muddy River. Although the Muddy River may not be a likely candidate for recreation activities that occur in and on the water, the fact that there is flowing water present during the months when recreation is likely to take place and the river is in close proximity to residential areas, the possibility exists that people, particularly children, may engage or are likely to engage in recreation activities involving contact with the water. As the demographics of

the lower Moapa Valley continue to change with residential subdivisions being built on land which was formally agricultural fields, more families with children will be living in close proximity to the lower Muddy River and the possibility exists for children to use the lower river for water related recreational activities especially during the summer months. Therefore, it is proposed to add the beneficial use "recreation involving contact with the water" to all reaches of the Muddy River and adopt appropriate bacteria water quality criteria to protect this use.

6.2.a Proposed Revision to the Location of the Beneficial Uses for Muddy River

It is proposed to list the beneficial uses for the three reaches of the Muddy River in the tables of water quality standards specific to each reach. This proposed revision is shown in the standards of water quality tables contained in Section 17.0. Currently, the beneficial uses for these waters are listed in two different water quality regulations (NAC 445A.174 and NAC 445A.209).

6.2.b Rationale for Proposed Revision to the Location of the Beneficial Uses for the Muddy River

Listing the beneficial uses in the tables of water quality standards for each reach of the Muddy River will permit respective water quality criteria and associated beneficial uses to be more easily compared.

7.0 Discussion of Proposed Numeric Criteria Revisions and Water Quality Data

New and/or revised numeric water quality criteria for color, *E. coli* bacteria, temperature, fluoride, and boron are proposed. The proposed revisions are individually discussed in subsequent sections.

Available water quality monitoring data from the Muddy River was used to develop new water quality criteria and to evaluate attainment of the revised criteria values. Water quality data used for this analysis and evaluation included water chemistry data collected by NDEP-BWQP during routine chemical monitoring of the Muddy River at Warm Springs Road, Glendale Bridge, Wells Siding, and at Overton; historical water quality measurements made by the United States Geological Survey (USGS) on the upper Muddy River at the Moapa gage; and water chemistry results provided by an outside entity collected from the lower Muddy River at Lewis Avenue in Overton.

8.0 Color Water Quality Criteria

Proposed Revision to Color Water Quality Criteria

It is proposed to replace the existing narrative color water quality criteria for the upper reach (NAC 445A.210) which states "increase in color must not be more than 10 PCU above natural conditions" with a numeric criteria of ≤ 75 PCU. This criteria has been recommended by USEPA for protection of the use of municipal and domestic supply (USEPA 1986).

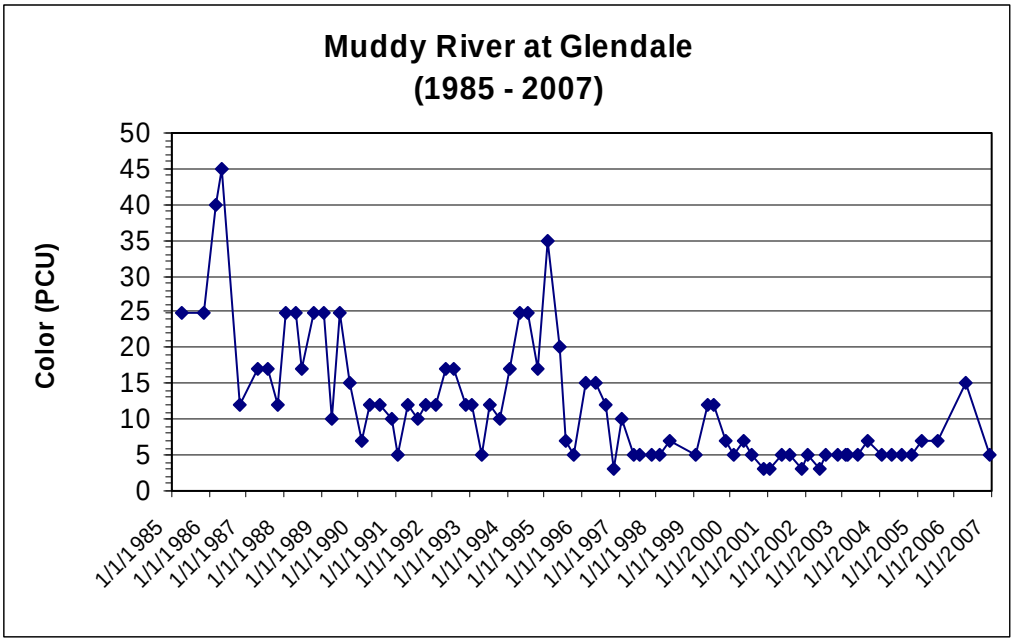
Rationale for Proposed Revisions to Color Water Quality Criteria

The color of a surface water body is an important constituent in terms of aesthetic consideration. Color in water results primarily from degradation of naturally occurring organic matter. The major surface waters contained in the State of Nevada water quality regulations have color criteria of ≤ 75 PCU for protection of municipal and domestic supply beneficial use. It is proposed to adopt this color water quality criteria value for the upper reach of the Muddy River. A numerical limit will allow compliance to be more easily evaluated.

Discussion of Color Water Quality Data

Color values measured in the Muddy River at the Glendale Bridge are shown in Figure 6. The color values measured over the time period 1985 to 2007 are below the proposed water quality criteria of 75 PCU.

Figure 6
Color Levels in Upper Reach



9.0 *E. coli* Bacteria Water Quality Criteria

Proposed Revisions to the *E. coli* Bacteria Water Quality Criteria

The three reaches of the Muddy River are recommended to have a beneficial use of water contact recreation and the following *E. coli* water quality criteria are proposed to protect this use.

Annual Geometric Mean (A.G.M.)	≤ 126 per 100 ml
Singe Sample Value (S.V.)	≤ 410 per 100 ml

The existing *E. coli* criteria of ≤ 630 per 100 ml (annual geometric mean) will be replaced with the above proposed *E. coli* values.

Rationale for Proposed Revisions to the *E. coli* Bacteria Water Quality Criteria

USEPA has recommended that *E. coli* be used as the indicator organism to evaluate whether pathogens are present in the waterbody at concentrations that could potentially cause human health risks (USEPA Ambient Water Quality Criteria for Bacteria – 1986). These indicator organisms are often not the direct cause of an illness, but have demonstrated characteristics that make them good predictors of whether harmful pathogens, such as viruses, protoza, bacteria, and other disease-causing microorganisms, are present in the water bodies. The bacteria water quality criteria are levels of indicator organisms that should not be exceeded in order to protect human health from pathogen-caused illness. Water bodies may contain many different pathogens that cannot be measured directly; therefore, indicator organisms are used to predict the health risks from pathogens residing in the water bodies.

"Recreation involving contact with the water" has been proposed to be added as a beneficial use for the Muddy River from its origin in the Warm Springs area to its terminus at Lake Mead. The above *E. coli* water quality criteria will provide a level of protection to human health during water contact recreation activities that may occur on and in water, and the possibility exists for immersion in and ingestion of the water. Similar *E. coli* water quality standards have been adopted for other surface water bodies in the State that have a beneficial use of water contact recreation. The *E. coli* water quality criteria are proposed to protect human health during water contact recreation activities, but they will also be protective of the beneficial use of non-water contact recreation.

Although *E. coli* water quality criteria are proposed to protect human health during recreational activities involving contact with the water, as well as non-water contact recreational activities, the existing fecal coliform bacteria criteria for the Muddy River

will be retained. The fecal coliform criteria will still provide a level of protection for non-contact water recreation as well as other beneficial uses on the Muddy River.

Discussion of *E. coli* Bacteria Water Quality Data

Upper Reach

E. coli levels measured in the upper reach at Glendale Bridge from 1995 to 2007 are shown in Figure 7. A comparison of the measured *E. coli* levels to the proposed single-value BUS of 410 per 100 ml is shown in the figure. *E. coli* levels measured in the samples collected over this time period are compared to the proposed standards in Table 2. Analysis of river water samples for *E. coli*, on a regular basis, was not started until 1995. The proposed *E. coli* single-value of 410 per 100 ml is usually attained in the upper Muddy River. Although several of the samples collected during 1996 to 1997 were above this proposed value, the *E. coli* levels in the upper Muddy since 1998 have been at or below the proposed single-value criteria of 410 per 100ml. Compliance with the proposed *E. coli* A.G.M. is not as good. However, for several years during 1995 to 2004, the A.G.M.s were calculated based on only one or two *E. coli* samples having been analyzed during the year. A more robust set of *E. coli* samples collected over an annual basis is required to better evaluate how the upper Muddy water quality compares to the proposed annual geometric mean.

Figure 7
***E. coli* Levels in Upper Reach**

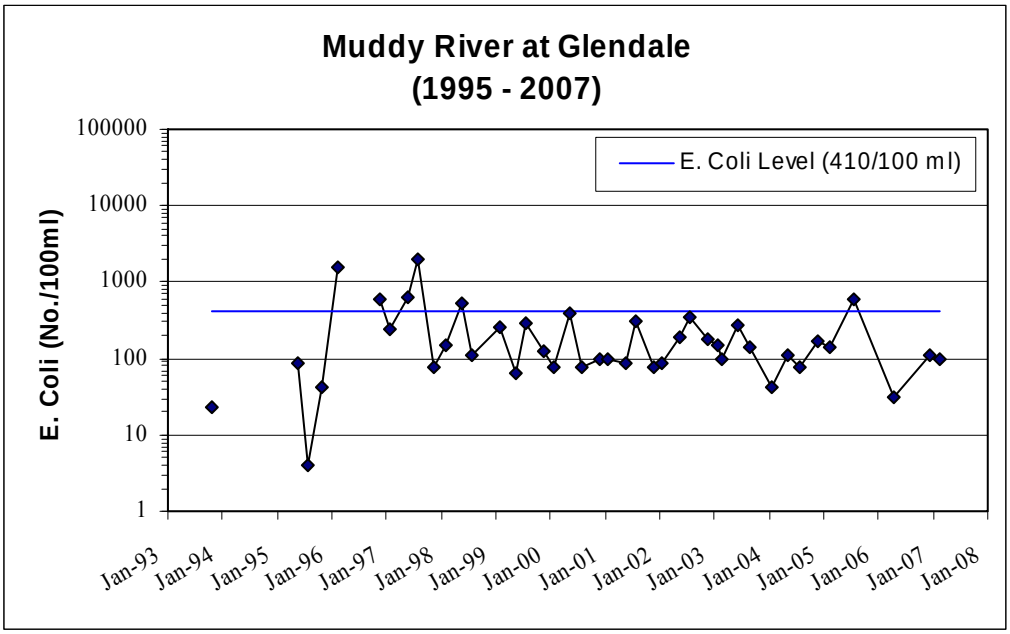


Table 2. *E. coli* Data for Upper Reach at Glendale Bridge.

Period of Record	Proposed Standard	Number Samples	Number Samples Exceeding	Percent Samples Exceeding
1995 – 2006	126 (A.G.M.) 410 (S.V.)	12 40	7 6	58% 15%
2001 – 2006	126 (A.G.M.) 410 (S.V.)	6 20	3 1	50% 5%

Middle Reach

Water quality monitoring has only recently been initiated at the lower end of the middle reach and only one year of sample results are available. *E. coli* levels in the samples at Wells Siding diversion have ranged from 20 per 100ml to 306 per 100ml with an average of 127 per 100ml.

Lower Reach

E. coli levels measured in the lower Muddy River from 1995 to 2005 at Overton are shown in Figure 8. Comparison to the proposed single-value criteria of 410 per 100 ml is shown in the figure. Annual geometric mean values calculated from the available *E. coli* data are shown in Table 3. In 2006, the monitoring point for the lower reach was moved further downstream to below the Overton Wildlife Management Area diversion. *E. coli* levels measured over the past year at this new monitoring point have ranged from 31 per 100 ml to 222 per 100ml with an average of 107 per 100ml. The *E. coli* levels in the lower reach are generally below the protective water quality numeric values proposed for water contact recreation.

Figure 8
***E. coli* Levels in Lower Reach**

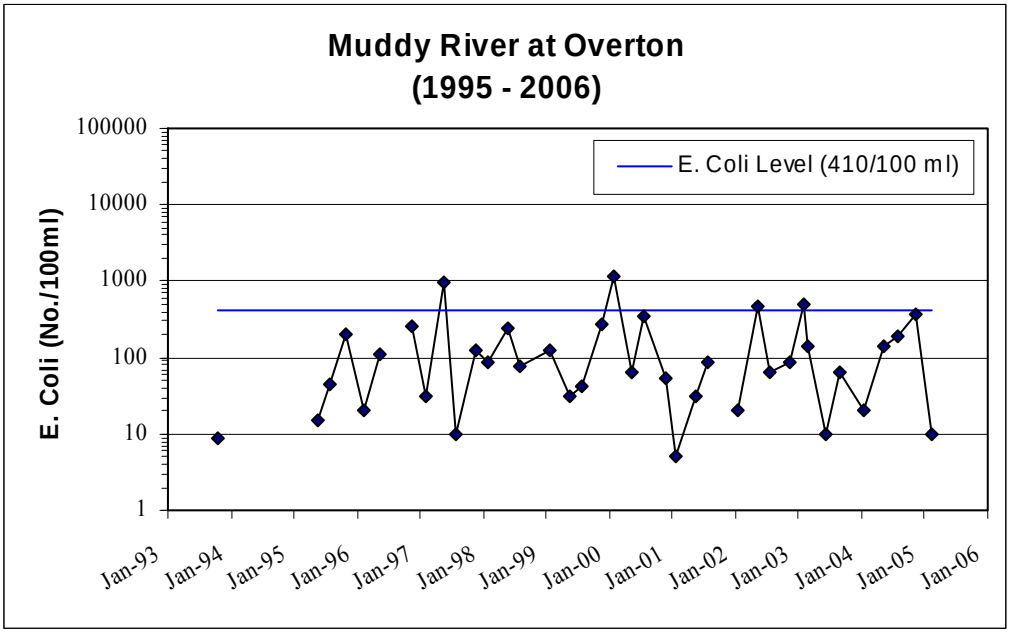


Table 3. *E. coli* Data for Lower Reach at Overton.

Period of Record	Proposed Standard	Number Samples	Number Samples Exceeding	Percent Samples Exceeding
1995 – 2006	126 (A.G.M.) 410 (S.V.)	10 38	1 4	10% 11%

10.0 Anti-Degradation Water Quality Objectives for Middle Reach

At this time, no anti-degradation water quality objectives are proposed for the new middle reach. Anti-degradation objectives (Requirements to Maintain Existing Higher Quality – RMHQs) are established when monitoring data shows that existing water quality for individual parameters is significantly better than the beneficial use standards. (Significantly better than the beneficial use standard is usually defined as less than 5 percent exceedance of the beneficial use standard). Under current NDEP-BWQP policy, RMHQs are only proposed when there are five or more years of data with a minimum of two samples per year.

A monitoring site was established by NDEP at the Wells Siding diversion to collect and assess water quality data at the lower end of the new middle reach. However, only one year of monitoring data has been collected from this site which doesn't meet the policy that has been followed to establish RMHQs for Nevada surface waters. Using water quality data from the upper and lower reaches of the river is not appropriate due to the differences in the hydrology and water quality of the different sections of the Muddy River. Additional monitoring data from the Wells Siding diversion monitoring site is required before an evaluation can be made regarding whether RMHQs should be established for this section of the Muddy River.

11.0 Temperature Water Quality Criteria

Background

Generally, numeric temperature criteria contained in Nevada's water quality regulations are intended to protect aquatic life, particularly native fish species which may be or have been present in a water body or a specific reach of a water body. It is assumed that the recommended temperatures to protect the various life stages of fish will also protect other forms of aquatic life in the water body. The temperature criteria are set as thresholds to not only prevent fish mortality but also to limit biodegradation of organic material in both

the overlying water and bottom sediments which can place an increased demand on available dissolved oxygen. The situation is aggravated during the summer because oxygen is less soluble with increasing water temperatures, resulting in lower dissolved oxygen concentrations. The number and distribution of benthic invertebrates also decreases as water temperature increases.

Native Fish Fauna

The thermal springs which combine to form the Muddy River create a situation where water with higher temperatures is present in the headwaters and the river water cools as it flows downstream. This is opposite of the temperature trends which are observed in most other river systems. The fish assemblages of the Muddy River are characteristic of an isolated southwestern desert habitat, comprising few species and harboring endemic forms. Two of the river's four native fish species, Moapa dace and Moapa White River springfish are thermophilic and endemic to the local headwaters areas and tributary thermal springs (Warm Springs area), typically in water with temperatures ranging from 19.0 °C to 32.0 °C and low turbidity. Adult Moapa dace primarily inhabit the upper section of the Muddy River above Warm Springs Road. Reproduction occurs year-round but is confined to the upper warmer thermal spring outflows where temperatures vary between 29.0 °C and 32.2 °C (USFWS 1996; Scoppettone 1993).

Distribution of Moapa White River springfish is primarily in the upper source springs and spring outflow habitats although their presence has also been documented in the upper Muddy River above the Warm Springs Road crossing. Springfish are extremely tolerant of high water temperatures and low dissolved oxygen levels, and reproduce year-round in the thermal tributary-spring environments (Deacon and Bradley 1972; Scoppettone 1993).

The two other native fishes, the Virgin River chub and the Moapa speckled dace, are non-thermophilic and are generally found in the cooler water downstream from the Warm Springs area. In the Muddy River, chub use the main stem channel for habitat and have

been collected in water temperatures between 15.0 °C – 30.0 °C (USFWS 1996). Historic data suggests chub were rare in the upper Muddy River above Warm Springs Road crossing but occurred throughout the middle and lower reaches as far downstream as the vicinity of Logandale (Deacon and Bradley 1972). In historic collections, chub abundance was highest in the middle Muddy River where water temperatures ranged from 16.0 °C to 26.0 °C. Current distribution is primarily in the middle reaches of the river downstream of Warm Springs Road to the Glendale area. Chub are rarely captured downstream of Glendale anymore, due to cumulative effects of habitat modification and seasonal alterations of river flows for agriculture, as well as, an increase in the number of non-native competitive and predatory fish species (Scoppettone et al 1998; Deacon and Bradley 1972).

Distribution of the Moapa speckled dace in the Muddy River is similar to that of the Virgin River chub. Based on this distribution, temperature requirements for the speckled dace are similar to the chub in the Muddy River. Moapa speckled dace are primarily found in the section of the river between the Warm Springs Road crossing and Glendale. Historically, speckled dace have been collected from the middle river reaches where summer maximum temperatures have ranged from 27.5 °C to 30.0 °C (Cross 1976; USFWS 1996). Occurrences in areas of the river downstream of Glendale have not been routinely documented.

Habitat alteration and introduction of non-native fish species have been identified as a major cause for the decline in Muddy River fish populations. Two non-native fish species – the western mosquitofish and short-fin molly – are established within the range of the Moapa dace and Moapa White River springfish (Scoppettone 1993). Both of these non-natives have had a negative impact on the Moapa dace population in the Warm Springs area. A more recent addition to the Muddy fish fauna is blue tilapia (Scoppettone et al. 1998; USFWS 1996). The presence of this non-native specie has the potential to cause substantial negative impacts to not only Moapa dace habitat but also habitats of other native fish species in the Muddy River ecosystem.

Historically, fish surveys have found native species to decrease and non-natives to increase in a downstream direction. However, more recent surveys have found a decrease in number of all species in a downstream direction (Deacon and Bradley 1972). Native fish species have not been found in the lower reaches of the Muddy River. Below the Bowman Reservoir diversion dam at Wells Siding, the water quality and seasonal flow fluctuations limit the potential for a sustainable native fish population. The water in the river channel below Wells Siding is predominantly irrigation tail water containing excess dissolved salts and a high silt content. As the volume of fresh water delivered to the lower Muddy River is reduced by upstream agricultural diversions, and the level of dissolved salts and other constituents are further concentrated by irrigation return flows, the overall effect is that the water quality in the lower Muddy River is adversely impacted. Occasionally, some fish occur in this section of the river, particularly when Lake Mead water levels are high and waters back up the river (USFWS 1996).

An overview of the Muddy River system showing the distribution of native fish populations is shown in Figures 9 a–b. The water temperatures of the different sections of the Muddy River used for habitat by these fish species are shown in the figures. These temperature ranges were discussed above and have either been reported in the literature or determined by field measurements during fish surveys.

Figure 9 a. Native Fish Distribution in Upper Muddy River Corridor.

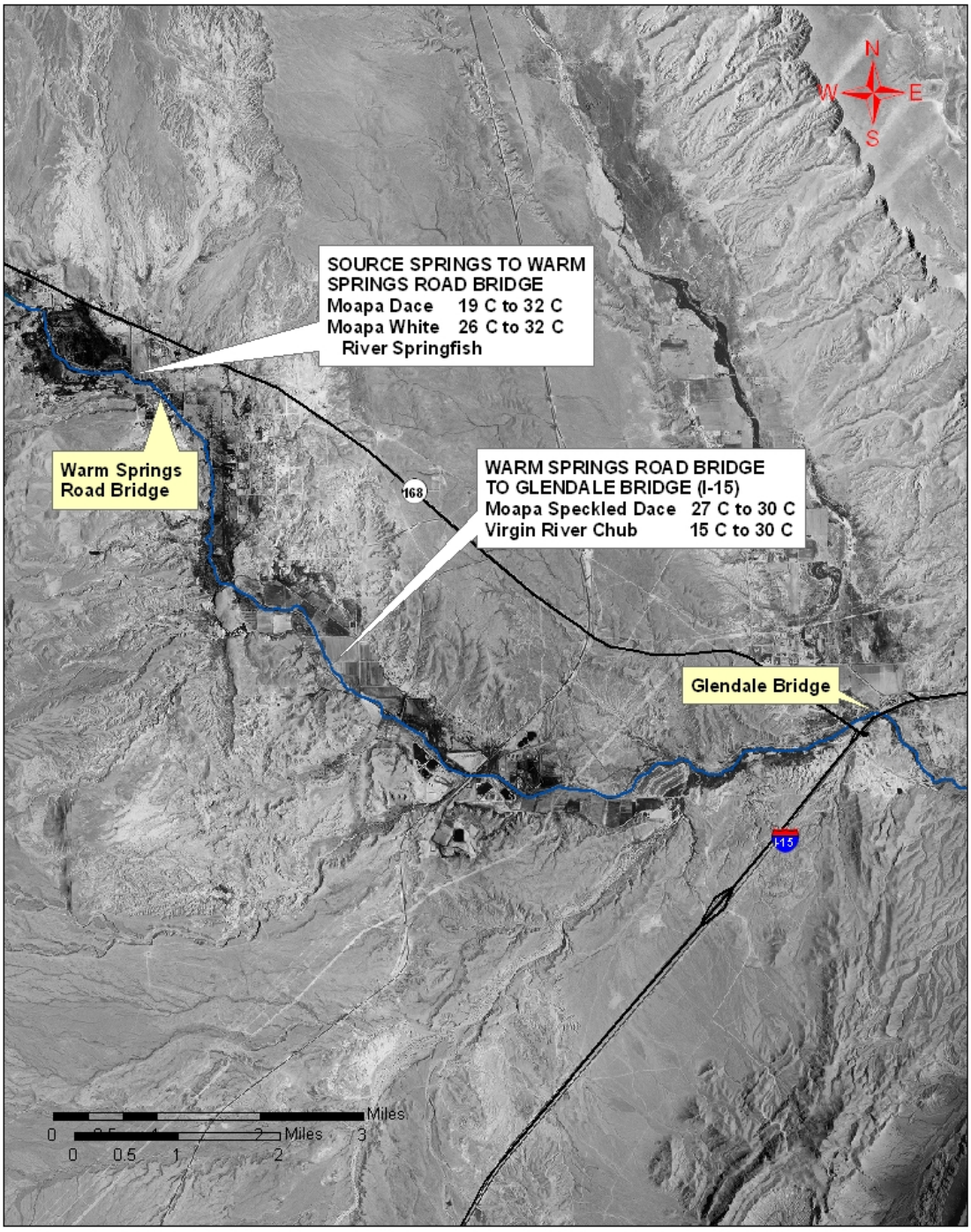
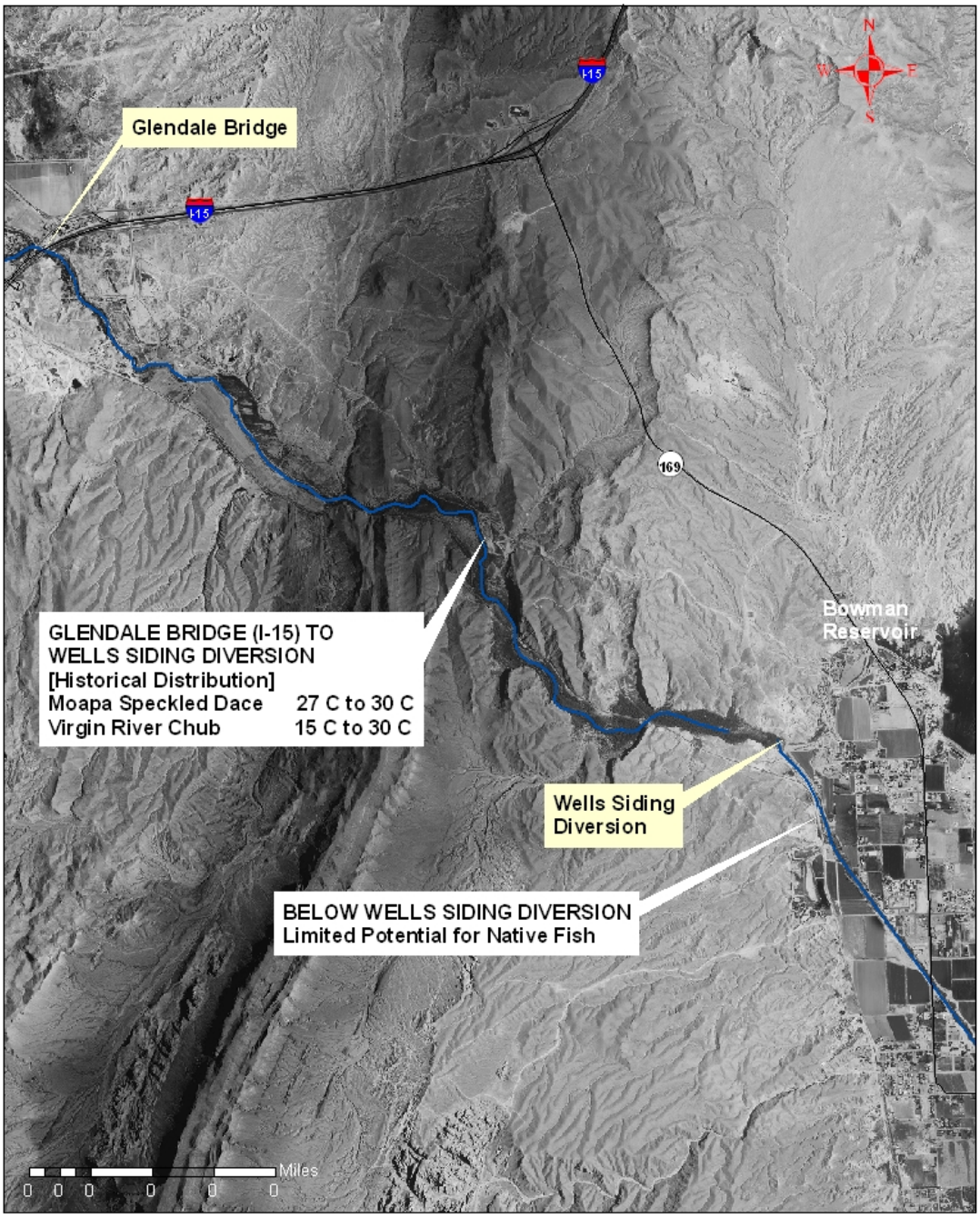


Figure 9 b. Native Fish Distribution (historically) in Middle Muddy River



Proposed Revisions to Temperature Water Quality Criteria

The current temperature criteria for the Muddy River are seasonal single-values: ≤21 °C during November through June and ≤32 °C from July through October. There is limited information in the BWQP files to explain how the seasonal numerical temperature values were derived and what aquatic life species or life-stages they were intended to protect.

The proposed revisions to the temperature water quality criteria were developed through a series of consultation meetings with NDOW and USFWS. The revisions are based on the habitat temperature requirements of the endemic native fish species that occupy various sections of the Muddy River (see Figures 9a and 9b). This spatial distribution and temperature requirements of the endemic fish species within the river system can be correlated to the three reaches which have been proposed to segment the Muddy River, as explained below.

In the upper Muddy River, the Warm Springs road crossing functionally separates the upper reach into two fish fauna classifications, as illustrated in Figure 9a. Moapa dace and Moapa White River springfish inhabit the section of the river upstream of the Warm Springs Road bridge, while Moapa speckled dace and Virgin River chub occupy the section of the river below the Warm Springs Road bridge (USFWS 1996). Even if the Warm Springs Road crossing and current upstream physical barriers (Moapa streamflow gage station and Nevada Power Company diversion structure) did not exist, it is anticipated that there would still be a segregation of native fish species in the upper Muddy due to the different habitat temperature preferences of the endemic fish species based on discussions with NDOW and USFWS personnel.

The Warm Springs Road crossing acts as a physical demarcation that divides the upper Muddy into two temperature regimes. Temperature water quality criteria are proposed for the two sections of the upper Muddy River.

For the section of the upper Muddy River from the source springs to the Warm Springs Road crossing, a water temperature criteria of 19 °C ≤ T ≤ 32 °C is proposed. This temperature range rather than an absolute temperature value is supportive of Moapa dace and Moapa River springfish which inhabit this section of the river (USFWS 1996).

A temperature criteria of 15 °C ≤ T ≤ 30 °C is proposed for the Muddy River from the Warm Springs Road bridge down to the Glendale Bridge. Based on discussion with NDOW and USFWS personnel, the 30 °C upper temperature range value is the desired upper threshold value that would not impact the native fish species in this section of the upper Muddy River. The proposed upper threshold value of 30 °C rather than 32 °C also reflects the natural cooling of the water as it flows downstream. Virgin River chub and Moapa speckled dace which occupy the lower section of the upper Muddy River reach would be protected with the proposed water temperature range (USFWS 1996).

The proposed middle reach extends from the Glendale Bridge downstream to the diversion facility for Bowman Reservoir at Wells Siding. Historically, Virgin River chub were found in this stretch of the river, as far downstream as the town of Logandale (see Figure 9b). Although habitat modification and seasonal flow alterations for agriculture have forced the majority of chub upstream, recent surveys have found small numbers of chub present in some of the historic habitats within this reach of the river (Deacon and Bradley 1972). A proposed temperature range of 15 °C ≤ T ≤ 30 °C is proposed for the middle Muddy River reach.

Proposed temperature criteria for the upper and middle reaches of the Muddy would no longer be seasonal values but instead would be temperature ranges that would be applicable year round. The temperature ranges reflect the habitat temperature preferences of the native fish species documented in these sections of the Muddy River. The proposed critera also capture the range of natural temperature fluctuations on a seasonal basis.

Native fish species are rarely found in the lower reach of the Muddy River. Below the Wells Siding diversion, changes to water quality, agricultural flow alterations, and loss/modification of habitat limit the potential for sensitive native fish species to propagate in the lower Muddy River. The NDOW which receives water from the lower Muddy River does not operate a managed fishery at the Overton Wildlife Management Area, although some of the ponds at the refuge are used to "grow-out" juvenile and young adult warm water fish species (in particular, razor-back suckers). A single upper level temperature threshold rather than a temperature range is proposed for the lowermost section of the Muddy River. NDOW and USFWS have recommended a value of less than or equal to 32 °C as a reasonable temperature criteria to sustain warm water fish species that may occur in this section of the river.

The existing temperature standards include a $\Delta T \leq 2°C$ which applies to the maximum allowable increase in temperature above the temperature of the river water at the boundary of an approved mixing zone, but the increase must not cause a violation of the single value standard. This ΔT value will be retained with the revised water temperature criteria. The proposed temperature revisions for the Muddy River are summarized below.

Table 4. Proposed Temperature Water Quality Criteria for the Muddy River.

Muddy River	**Existing Criteria**	**Proposed Criteria**
Upper Reach		
Source Springs to Glendale Bridge	$T \leq 21$ °C <Nov-June> $T \leq 32$ °C <July-Oct> $\Delta T \leq 2°C$	----
Source Springs to Warm Springs Road		19 °C $\leq T \leq$ 32 °C
Warm Springs Road to Glendale Bridge		15 °C $\leq T \leq$ 30 °C $\Delta T \leq 2°C$
Middle Reach		
Glendale Bridge to Wells Siding diversion	$T \leq 21$ °C <Nov-June> $T \leq 32$ °C <July-Oct> $\Delta T \leq 2°C$	15 °C $\leq T \leq$ 30 °C $\Delta T \leq 2°C$
Lower Reach		
Wells Siding diversion to Lake Mead	$T \leq 21$ °C <Nov-June> $T \leq 32$ °C <July-Oct> $\Delta T \leq 2°C$	$T \leq 32$ °C $\Delta T \leq 2°C$

Anti-degradation Temperature Water Quality Standards (RMHQs)

The existing temperature criteria for the Muddy River (NAC 445A.210 and NAC 445A.211) also contain anti-degradation values (RMHQ) of $\Delta T = 0$ °C. In the mid-1980s, a conservative control strategy was implemented by NDEP to ensure that any existing or future discharges to Nevada surface waterbodies would not impact the existing temperature regimes in the waterbodies. This control strategy involved adopting an anti-degradation temperature criteria (RMHQ) of 0 °C to assure that any discharge would not cause a rise in the temperature of the receiving waterbody, after the discharge mixed with the receiving water in an approved mixing zone. The temperature RMHQ of 0 °C was adopted on a state-wide basis and incorporated into most of the water quality regulations.

Although the intent of this strategy was to ensure that the existing temperature water quality conditions would be maintained, no guidance was developed on whether the RMHQ ΔT criteria were to be applied and assessed on an absolute temperature basis, a daily average, a daily maximum value, or based on some other time duration. The interpretation and implementation of the ΔT temperature criteria is currently being addressed by NDEP-BWQP. Until more definitive guidance is promulgated for addressing the ΔT requirements, the existing RMHQ ΔT criteria will be retained.

Discussion of Temperature Water Quality Data

Water temperature values measured at Warm Springs road, Glendale, and Overton are shown in Figures 10 a-d, respectively. At each location, the temperature of the river varies significantly from month to month and from year to year. The water temperature values only reflect a point in time when the measurement was made which can be influenced by the time of day that the measurement was taken, the ambient air temperature, and the volume of water flowing in the river channel. In each figure, the corresponding temperatures proposed as water quality criteria for the reach in which the measurements were made are shown. The measured water temperatures have been within the range of temperature values proposed as water quality criteria.

Figure 10a
Temperature Values in Upper Reach (USGS)

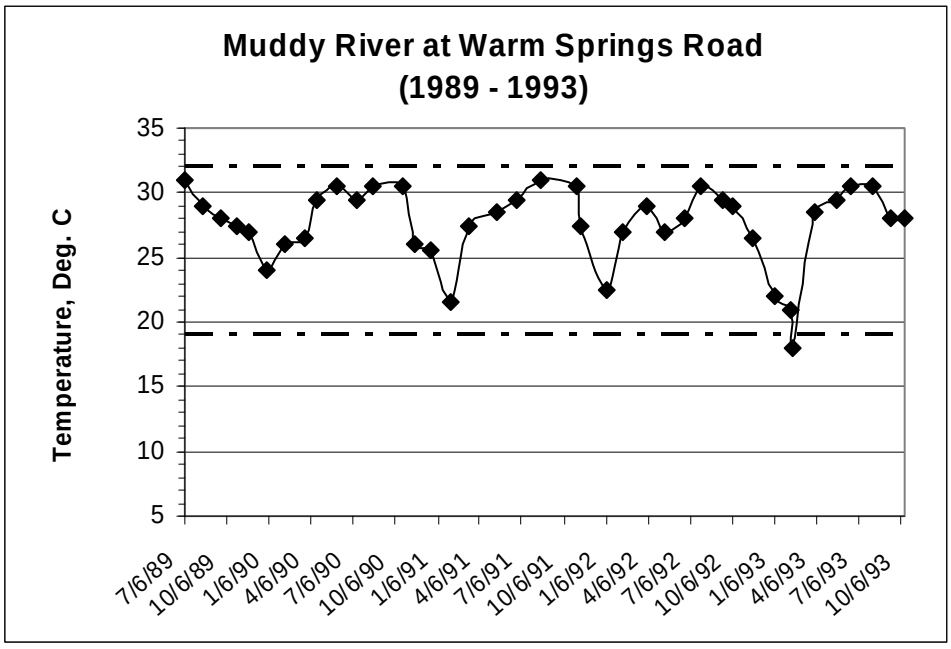


Figure 10b
Temperature Values in Upper Reach (NDEP)

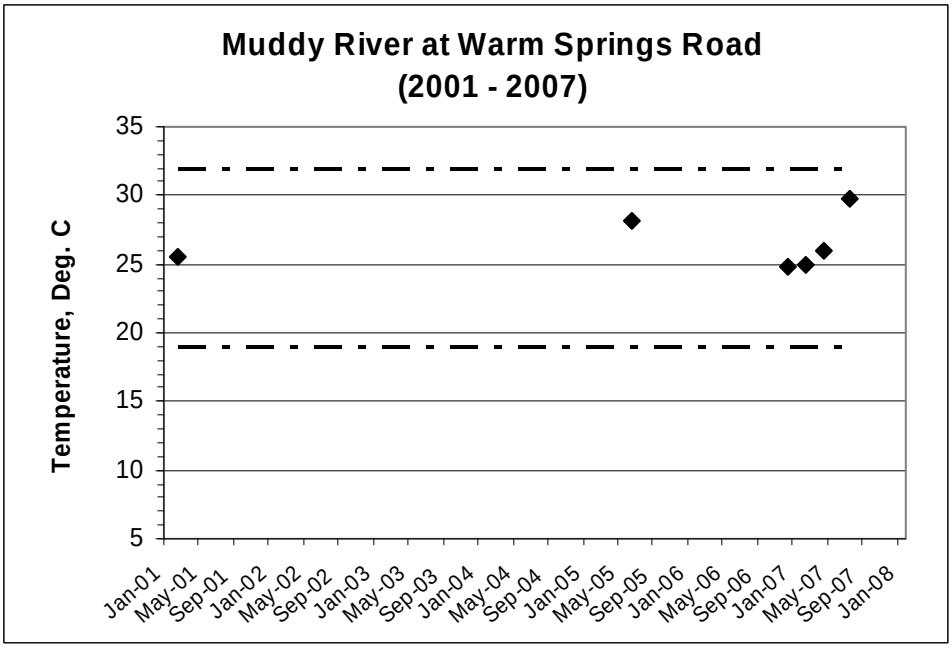


Figure 10c

Temperature Values at Glendale Bridge

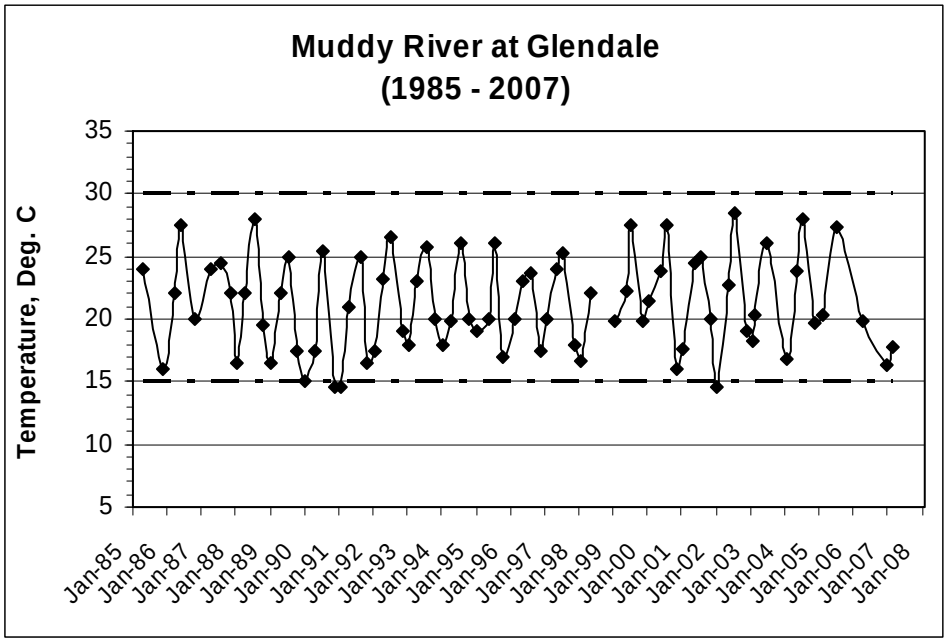
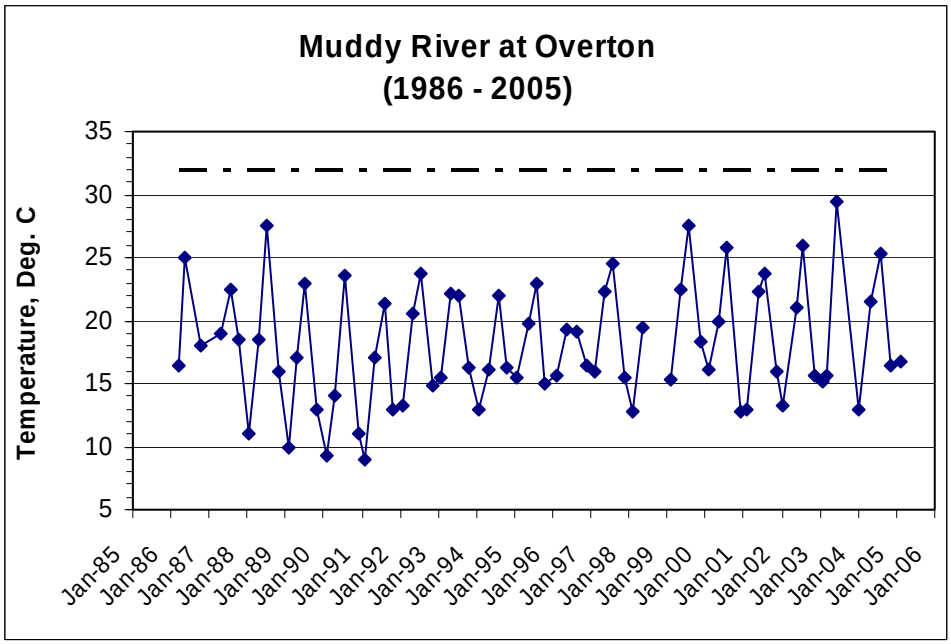


Figure 10d
Temperature Values at Overton



The temperature values shown in Figure 10a are the historical measurements made by the USGS at the Moapa gage, located on the upstream side of the Warm Springs Road crossing. Water chemistry monitoring by the USGS at the Moapa gage was stopped in 1993. Figure 10b shows the water temperatures measured by NDEP-BWQP at the Warm Springs road crossing in 2001, 2006, and 2007.

A water chemistry monitoring station was only recently established for the proposed middle reach at the Wells Siding diversion. Water temperature values measured at this location over the period December 2006 to July 2007 ranged from a low of 16.5 °C to a high of 27.2 °C. The measured temperatures have been within the 15 °C to 30 °C range proposed as water quality criteria for the middle reach.

The water chemistry monitoring station for the lower reach was moved from the town of Overton downstream to below the NDOW diversion structure at the Overton Wildlife Management Area. Water temperatures measured at this new monitoring site from December 2006 to July 2007 ranged from 10.6 °C to 27 °C. Temperatures have been below the proposed criteria of 32 °C for the lower reach.

12.0 Fluoride Water Quality Criteria

The fluoride water quality criteria contained in NAC 445A.144 which are applicable to Nevada surface waters are 1.0 mg/l (1,000 µg/l) for irrigation use and 2.0 mg/l (2,000 µg/l) for livestock watering. Fluoride levels in the Muddy River naturally exceed the fluoride irrigation and livestock watering criteria values. The springs in the Warm Springs area which constitute the source of the Muddy River generally have fluoride concentrations greater than 2 mg/l. Baldwin and Jones springs, two of the major springs in the Warm Springs area, have been routinely sampled by the Moapa Valley Water District (MVWD). Discharges from both of these springs are collected by MVWD and combined with groundwater from wells in the vicinity of the springs to supply potable water for the Moapa Valley. Sampling records from MVWD over the time period 1998 to 2006 showed fluoride levels in these springs ranged from 2.1 mg/l to 2.3 mg/l. The

overall water quality is good based on MVWD records although the fluoride concentration is above the desired State of Nevada standard of 2.0 mg/l (2000 µg/l) for community water systems. The MVWD has been granted a variance by the State of Nevada (Bureau of Safe Drinking Water) allowing the fluoride levels to be higher than 2000 µg/l in the water supplied to consumers.

The USGS has operated a gaging station (Moapa gage) on the Muddy River (upstream of the Warm Springs Road crossing, see Figure 3). Water chemistry data collected by the USGS at the Moapa gage showed that fluoride levels in the river ranged from 1.4 mg/l to 2.6 mg/l based on sampling records over the time period 1989 to 1993. The NDEP-BWQP has recently started to collect water chemistry samples of the Muddy River near the gaging station at the Warm Springs Road crossing. Fluoride levels in samples collected from June 2005 to July 2007 have ranged from 2.2 to 2.3 mg/l. A summary of the fluoride levels in samples collected from the upper Muddy River by the USGS and NDEP-BWQP is shown in Table 5. The water chemistry data have shown that fluoride concentrations in the river are consistently high and similar to the natural background levels of fluoride in the source springs. The elevated fluoride levels are not attenuated as the Muddy flows downstream. At the Glendale bridge, which is approximately 10 to 11 miles downstream from the Moapa gage, fluoride levels of 2.3 mg/l to 2.6 mg/l have been measured in samples collected from July 2004 to February 2007. Over this same time period, fluoride levels in the river further downstream at Overton have ranged from 2.4 mg/l to 3.3 mg/l. The water in the river channel at Overton is primarily irrigation return flows (tail water) and the increase in fluoride concentrations detected downstream are due to irrigation practices causing evaporation of flows and concentration of salt levels in the return flow water.

Water samples taken at Bowman Reservoir from March 2006 through October 2006 have shown that the fluoride concentration in surface samples ranged from 2.2 mg/l to 2.8 mg/l with an average of 2.5 mg/l. Samples taken of the discharge from Bowman Reservoir during September 2006 showed that the fluoride level in the water leaving the reservoir

was 3.0 mg/l (Source: Southern Nevada Water Authority, Chemical Monitoring Results from Muddy River).

Table 5. Fluoride Levels Measured in Upper Muddy River.

FLUORIDE LEVELS – UPPER MUDDY RIVER	
Date	Fluoride as mg/l
July 1989	2.3 [USGS]
October 1989	2.4 [USGS]
February 1990	2.4 [USGS]
April 1990	2.3 [USGS]
July 1990	2.3 [USGS]
August 1990	2.6 [USGS]
November 1990	2.2 [USGS]
February 1991	2.0 [USGS]
May 1991	2.6 [USGS]
June 1991	2.0 [USGS]
October 1991	1.9 [USGS]
January 1992	2.2 [USGS]
June 1992	2.4 [USGS]
September 1992	2.2 [USGS]
November 1992	2.3 [USGS]
February 1993	1.4 [USGS]
April 1993	2.4 [USGS]
June 1993	2.4 [USGS]
June 2005	2.3 [BWQP]
December 2006	2.2 [BWQP]
February 2007	2.3 [BWQP]
April 2007	2.3 [BWQP]
July 2007	2.2 [BWQP]
Average	2.24
Range	1.4 to 2.6

The following sections include a review of the existing fluoride water quality standards; an evaluation of the more recent scientific information on the effects of fluoride to agricultural crops and livestock species; and the derivation of fluoride water quality criteria for the Muddy River. An evaluation of the protectiveness of the proposed values for beneficial uses on the Muddy River is also presented.

12.1 Review of Existing Standards

Irrigation

The USEPA recommended in "Water Quality Criteria, 1972" (Blue Book) a range of trace element concentrations for irrigation waters dependent on the type of soil. For fluoride, a level of 1.0 mg/l was recommended for waters used continuously on all soil types. The USEPA, however, also stated in the Blue Book that neutral to alkaline soils have a high capacity for inactivating fluoride, and that a recommended level of 15 mg/l fluoride in water could be tolerated on these types of soils over a time period of up to 20 years. These recommendations were developed based on results from experimental studies completed prior to 1972 which had investigated the accumulation and toxicity of fluoride in plants. In their discussion of these studies, the USEPA reported the results from a study that showed higher accumulation of fluoride in the bones of cattle grazed for over seven years on pastures fertilized with phosphate that contained high fluoride concentrations compared to cattle grazed on pastures with lower fluoride applications (USEPA 1972). The uptake and accumulation of fluoride in the plants and the subsequent secondary transfer of fluoride from the plants to animals may have been a concern and the lower fluoride irrigation criteria of 1.0 mg/l was recommended.

Livestock Watering

The limit for fluoride in livestock drinking water of 2.0 mg/l was based on the USEPA review of literature published in the 1960s to early 1970s. Many effects of fluoride exposure to livestock are similar to those reported for humans. Young animals are susceptible to dental effects, while older animals may develop skeletal fluorosis from long-tem exposure to elevated fluoride levels. When excessive amounts of fluoride are ingested for prolonged periods, chronic fluorosis may result (Shupe and Olson 1971). Chronic fluorosis in livestock is endemic to areas of India, Argentina, and Africa where well water contains 5 to 15 mg/l fluoride, and evapo-concentration of livestock watering areas can result in fluoride concentrations as high as 40 mg/l being consumed (USEPA 1972; Underwood and Suttle 1999).

Updating the "Blue Book" fluoride irrigation and livestock watering limits based on more recent scientific studies has not been promulgated by USEPA. While USEPA has not specifically reviewed and/or revised the trace elements limits recommended for irrigation and livestock watering uses, the USEPA has revised/updated the criteria values for most priority pollutants to protect human health and aquatic life. Generally these updated human health and aquatic life criteria values are sufficiently stringent to inherently protect irrigation and livestock watering uses. Fluoride is not considered a high priority pollutant. Since it is known to be much less toxic than many other metals and inorganic substances and is not known to be either carcinogenic or otherwise constitute a major threat to ecological systems, the USEPA has not developed more current water quality criteria for fluoride. Under the Clean Water Act, States have the option to specifically develop water quality criteria to protect the beneficial uses of a water body.

12.2 Review of the State-of-Science

Fluoride is the chemical form of fluorine that occurs in nature. Because fluoride is a common constituent of several relatively abundant minerals, it is a component of most soils, being associated with the colloidal or clay fractions. Elevated inorganic fluoride levels are often seen in regions where there is geothermal or volcanic activity. The transport and transformation of fluoride in water are influenced by pH, water hardness and the presence of ion-exchange materials such as clays (Bohn, McNeal, and O'Connor 1985). Transport and transformation are also influenced by the formation of calcium and aluminum complexes. Scientific studies to evaluate the potential biological and ecological significance of fluoride levels in water on plants and livestock indicate wide differences in the acceptable threshold values.

Irrigation

A number of soil characteristics, as well as other environmental factors, influence the availability of fluoride to plants. For example, fluoride is more readily available in acidic sandy soils than in high-clay soils. Neutral and alkaline soils have been shown to deactivate fluoride and/or restrict its mobility (Ministry of Environment 1995). Most

plants do not take up much fluoride from the soil or from irrigation water; the major fluoride source being airborne deposition. While fluoride is only weakly sorbed by soil exchange processes, it does strongly bind to iron and aluminum oxides and clay particles, limiting its availability to plants (Stevens et al. 2000). Generally, the amount of fluoride that can be taken up by a plant is small, and not related to the level in soil or irrigation water, but rather to soil type, soil pH, calcium and phosphorous levels and the plant species being grown (Ministry of Environment 1995). Fluoride-induced injury to plants results primarily from deposition and adsorption of soluble fluoride salts on the foliage of the plants. This deposition may result from splashing during irrigation or rainfall, or due to dust and particle suspension caused by cultivation and harvesting (Ministry of Environment 1995). The potential for fluoride injury to plants is reduced when farms use flood irrigation rather than sprinkler irrigation.

Results from recent studies investigating the toxicity of fluoride to plants have shown that there is a low degree of phytotoxic effects to the plant species tested. These results are shown in Table 6. Typical forage crops such as barley and oats are unaffected by concentrations of fluoride compounds ranging from 24 to 32 mg/l. These results are from hydroponic studies, where the soluble fluoride would be readily available to the plants (Stevens et al. 1997 and 2000). In actual irrigation practices, the soluble fluoride compounds in the field-applied irrigation would be even less available to the plants due to interactions with soil oxides and clay particles.

Table 6. Fluoride Toxicity to Plants.

Species	Fluoride Form	mg/l	Test Conditions	Effect	Reference
Oats	NaF	32		NOAEL Biomass	Stevens et al. 1997
Clover, scotch thistle	NH_4F	47.5	6 weeks	No effect on growth	Stevens et al. 2000
Orchardgrass, barley grass, sorrel	NH_4F	23.75	6 weeks	Decreased root and shoot biomass	Stevens et al. 2000
Tomatoes	NaF	32		Significantly decreased biomass	Stevens et al. 1997

Livestock Watering

Acceptable fluoride intake levels for livestock are a function of concentrations in feed (forage) and water. If forage concentrations are low, high concentrations can be tolerated in the water, and vice-versa. Researchers have concluded that cattle are the most sensitive livestock species, with sheep, hogs, horses, and poultry being more tolerant of fluoride concentrations in their forage and drinking water (Meyer et al. 1997; Puls 1994; Underwood and Suttle 1999). Dairy cattle are generally the target cattle livestock group used for evaluating fluoride threshold values (Puls 1994). This is because the effects from exposure to elevated fluoride levels are typically not observed until several years of exposure, and dairy cattle generally live longer than market beef cattle. The effects of fluoride in forage and drinking water of cattle is generally related to skeletal problems in the animals (National Academy of Sciences 1971). The addition of elevated fluoride levels to a dairy cow's food or water has little effect on fluoride levels in the milk (National Academy of Sciences 1974). The following fluoride threshold levels in the diet of cattle (Table 9) have been reported in the scientific literature (Puls 1994 and National Academy of Sciences 1971).

Table 7. Fluoride Threshold Levels in Water and Diet of Cattle.

Fluoride	Diet dry matter (mg/kg)	Drinking Water (mg/l)
Young Dairy Cattle	30	2.5 – 4.0
Mature Dairy Cattle	40	3 – 6
Mature Beef Cattle	50	4 - 8
Slaughter Cattle	100	12 – 15

Fluoride tolerance levels in feed range from 30 – 40 mg/Kg dry weight in dairy cattle to 100 mg/Kg in cattle designated for slaughter. In cattle drinking water, tolerance levels range from 2.5 – 4.0 mg/l for young dairy cattle and from 3.0 – 6.0 mg/l for mature dairy cattle. As shown above, beef cattle can withstand higher levels of fluoride in drinking water sources.

The Council for Agricultural Science and Technology (CAST), a non-profit consortium of food and agricultural scientists, recommended a fluoride limit of 3.0 mg/l as being potentially toxic in drinking water for livestock and poultry. CAST acknowledged that although the likelihood for fluorosis (mottling of teeth) would increase at this concentration, the accumulation of fluoride in the soft tissue of livestock and secondary transfer to the human population from consumption of animal products would not occur. A higher fluoride tolerance level was recommended by CAST because often the quality of livestock drinking water is a consequence of natural processes and the cost of improving the quality of the natural water supply in many instances would be prohibitive (CAST 1974).

12.3 Derivation of Proposed Fluoride Water Quality Criteria For the Upper and Middle Reaches

The combined data set of fluoride concentrations measured by the USGS and the NDEP-BWQP at Warm Springs Road (Table 5) were used to derive a proposed fluoride water quality criteria of 2.6 mg/l (2600 µg/l), as total recoverable fluoride, for the upper sections of the Muddy River. This value is representative of the 95th percentile value of the fluoride levels measured and reflects the naturally high fluoride concentrations in the source waters of the Muddy River. The 95th percentile is defined as the 95th ranked value of a sample population distributed into one hundred equal parts and is used in this analysis to establish a threshold of an acceptable fluoride level in the river that will be protective of the beneficial uses assigned to the Muddy River. The proposed fluoride water quality criteria of 2.6 mg/l would be applicable to the upper and middle reaches, as well as, Bowman Reservoir (see Figures 3 and 4). The fluoride criteria proposed for the lower reach of the Muddy River, from Wells Siding to Lake Mead, is discussed in a later section of this report.

12.4 Evaluation of the Proposed Fluoride Water Quality Criteria For the Upper and Middle Reaches

As water quality criteria are intended to protect/support the beneficial uses of a water body, it is necessary to evaluate whether the proposed fluoride criteria of 2.6 mg/l is

protective/supportive of the beneficial uses associated with the upper and middle reaches. Beneficial uses associated with the two upper sections of the Muddy River (from its origin to Glendale and from Glendale to Wells Siding diversion) were previously discussed in Section 6.0.

As previously mentioned, the proposed fluoride water quality criteria for the upper sections of the Muddy River is also proposed for Bowman Reservoir due to the manner by which the water flows in the upper Muddy are managed. At the Wells Siding diversion, Muddy River flows are diverted to fill Bowman Reservoir. During the summer agriculture growing season, water is released from the reservoir into the MVIC canal system to supplement irrigation water demands in the lower Moapa valley. The beneficial uses assigned to Bowman Reservoir are similar to those of the upper Muddy River. The evaluation of the proposed fluoride water quality criteria and the beneficial uses of the upper and middle reaches, presented below, would also be applicable to the beneficial uses associated with Bowman Reservoir.

Irrigation

The general consensus in the more recent scientific literature is that fluoride has a low degree of phytotoxic effects to plants. Uptake of fluoride from soil solutions is limited as the fluoride in irrigation waters strongly binds to iron and aluminum oxides and clay particles limiting its availability to plants. Neutral and alkaline soils have been reported to deactivate fluoride, and the presence of calcium and phosphorous in the soils and/or irrigation waters has been shown to limit the mobility of fluoride (Bohn, McNeal, O'Connor 1985). The susceptibility of plants to fluoride injury is more related to the absorption of soluble fluoride salts during spray irrigation and/or airborne deposition (Ministry of Environment 1995).

In the upper and lower Moapa Valley, the soils are classified as either old alluvial soils or recent alluvium material. The old alluvial soils were formed during the time when the Muddy River had no defined channel and spread out over the valley mainly in the form of

swamps. Subsequent floods caused the river to further spread out over the valley floors and deposit what is classified as recent alluvial soil which consists of fine sands to silty clays. The old alluvial soils which form the subsoil are made up of a complex arrangement of beds and lenses of stratified material consisting of clay loam or clay texture materials (Bureau of Reclamation 1951). Based on available USGS data and soil survey information from NRCS, the soils in the upper and lower Moapa Valleys are alkaline with pH values ranging from 7.9 to 9.0 with moderate calcium and organic contents. Due to the high pH and presence of clays, organic debris, and calcium in the Moapa Valley soils, irrigation waters containing high fluoride levels would be able to be tolerated which might otherwise not be possible in soils without the same characteristics.

Water from the Muddy River has been used for irrigation purposes as far back as the mid-1800s. Continued development of agricultural lands due to a readily available supply of irrigation water from the river resulted in the growth and development of the Moapa Valley. Crops grown in the valley have historically been irrigated with Muddy River water containing elevated fluoride levels without any reported phytotoxic effects to the irrigated crops. Fluoride toxicity to plants has been reported in the scientific literature to be more of a consequence from absorption of soluble fluoride salts on the foliage of forage plants, such as during spray irrigation, rather than uptake from the soils or irrigation water. Flood irrigation techniques, as currently used in the lower Moapa Valley, further minimize the potential for fluoride impacts to plants. As previously discussed, in the upper and lower Moapa Valley, the alkaline nature of the soils and associated clay, calcium, and organic levels have been beneficial in limiting the mobility of fluoride in the subsurface environment.

Several feasibility studies were conducted by the Bureau of Reclamation in the 1960s evaluating the agricultural potential of the Moapa Valley. In a 1971 report, *"Moapa Valley Pumping Project, Concluding Report"*, results from fluoride levels measured in water samples taken at 5 locations along the Muddy River over a 9-month period from July 7, 1965 through March 23, 1966 were presented (Bureau of Reclamation 1971). The fluoride analyses of these samples are reproduced in Table 8.

Table 8. Fluoride Levels in Muddy River (1965 – 1966)

Location	Fluoride Levels (as mg/l)
Home Ranch Weir (Moapa Gage)	1.31 to 2.60
Moapa Indian Diversion	1.11 to 4.90
Glendale Gage	1.34 to 4.60
Wells Siding diversion	1.40 to 4.40
Overton Wildlife Area	1.80 to 4.90

Only the range of fluoride levels measured in the samples collected at the 5-locations were included in the 1971 BOR report. The results show that fluoride levels in the upper and lower sections of the Muddy River have historically been elevated; the fluoride being above the USEPA recommended irrigation water quality criteria of 1.0 mg/l.

Today, the main use of Muddy River water in the Moapa Valley is still for irrigation. Statistics on agricultural activities in the Moapa Valley from the U.S. Department of Agriculture (USDA) indicate that alfalfa hay is the predominant crop grown, and of the 44 farms in the Logandale and Overton areas, only 18 harvested a crop (USDA 2002). Available water quality data show that average fluoride levels in Muddy River water used for irrigational purposes have ranged from 2.5 mg/l to 3.0 mg/l, and have not had a detrimental effect on the forage crops grown in the lower Moapa Valley. As such, the recommended fluoride water quality criteria of 2.6 mg/l which was derived based on the natural background fluoride levels will provide a level of protection for the existing and continual use of Muddy River water for cultivation of typical forage crops such as alfalfa and hay in the upper and lower Moapa Valley.

Livestock Watering

Because fluoride is a cumulative toxin, effects from exposure are typically not observed until after several years of exposure, which can be from either feed (forage) or supplied water, or a combination of the two. There is general concurrence in the scientific literature that cattle, in particular longer-lived dairy cattle, are the livestock species most sensitive to the effects of fluoride exposure.

The major livestock found in Moapa Valley have been dairy and beef cattle. Dairy operations were historically the principal livestock enterprise. Beef cattle have been raised in the Moapa Valley and are still raised today; however, there are no large commercial livestock operations. According to the Nevada State Dairy Commission statistics, although there are 33 dairy farms in the State of Nevada, none are currently operating in the Moapa Valley (Nevada State Dairy Commission 2007). Other livestock raised include horses, sheep, and lambs.

The proposed fluoride water quality criteria for the upper and middle reaches of the Muddy River of 2.6 mg/l is within the range of recommended fluoride levels in cattle drinking water that have been reported in the literature (Table 7). If dairy operations are not the major livestock industry, then depending on whether breeding cattle or finishing cattle are raised, tolerable levels of fluoride in livestock drinking water can range from 4 mg/l to 15 mg/l, respectively. Based on this information, the proposed fluoride criteria of 2.6 mg/l will be a protective value for potential uses of Muddy River water diverted at Wells Siding or supplied from Bowman Reservoir for livestock watering. As previously discussed in Section 12.2, horses, sheep, and lambs have higher thresholds to fluoride than cattle and consequently, the proposed fluoride standard will not impact these livestock types.

Municipal or Domestic Supply

The Moapa Valley Water District (MVWD) has a state-issued variance to supply water with elevated fluoride concentrations to domestic households in the Moapa Valley. Issuance of the variance implies that the use of this water for domestic purposes is protected even though fluoride levels exceed the State of Nevada standard for fluoride of 2.0 mg/l in community water systems. Records from MVWD have shown that fluoride levels in the water supplied have generally ranged from 2.1 mg/l to 2.3 mg/l. The water supplied by MVWD for domestic use does not include collection of surface water from the Muddy River. Since fluoride levels in the upper Muddy River near its headwaters are

similar to the fluoride concentrations measured in the springs (Baldwin and Jones) which are collected by MVWD for domestic supply purposes, the recommended fluoride standard of 2.6 mg/l will protect the potential municipal or domestic supply use which exists on the upper reach of the Muddy River.

Aquatic Life

The Muddy River provides habitat for several rare and unique minnow fish species. The Moapa dace and Moapa White River springfish are thermophillic and endemic to the upper Muddy River and tributary spring systems within the Warm Springs area. The Muddy River provides habitat for two other fishes: the Virgin River chub and Moapa speckled dace; and a variety of endemic aquatic invertebrates. The Virgin River chub and Moapa speckled dace have historically existed in the Muddy River, primarily below the Warm Springs area and as far downstream as the Wells Siding diversion.

The unique aquatic life community that exists in the Muddy River, particularly in the upper section of the river and in the headwaters, has not been impacted by the natural elevated fluoride levels in these waters. The proposed fluoride water quality criteria for the upper and middle reaches based on the natural background levels of fluoride will be protective of aquatic life fauna that exists in the upper and middle sections of the Muddy River.

Water-Contact Recreation

Recreation involving contact with the water has been proposed to be included as a beneficial use on the Muddy River. Natural thermal springs in the Warm Springs area have been developed for recreational uses; providing the basis for two resorts which were operational for a number of years. Water from the springs was used to create swimming pools at these resorts. Since recreational activities involving contact with the water has previously occurred in spring waters having naturally high fluoride levels, the proposed fluoride criteria will be protective of water contact recreational activities that may take

place in the Muddy River. At this time, a fluoride criteria value to protect human health during water recreation activities has not been promulgated by the USEPA.

Non-Contact Recreation

Water-related recreation activities not involving contact with the water is a current beneficial use on the Muddy River. As mentioned above, a fluoride criteria value to protect human health during water recreation activities which may or may not involve contact with the water has not been promulgated by the USEPA.

Wildlife

The major wildlife use along the Muddy River corridor is at the Nevada Division of Wildlife (NDOW) Overton Wildlife Management Area. This facility is located at the lower end of the river system. Muddy River water utilized at the Wildlife Management Area is primarily irrigation tail water that returns to the river channel below the Wells Siding diversion via a network of agricultural drains. The utilization of the irrigation return flows by NDOW for wildlife related purposes will be discussed in more detail in a subsequent section of this report.

Fluoride threshold values for protecting wildlife have not been investigated by USEPA, nor has an interim water quality criteria been recommended. For other pollutants where data are unavailable on the effects of the pollutant on wildlife, USEPA has recommended that the criteria for livestock protection be applied to protect wildlife also. The limitations of the current USEPA Blue Book (1972) livestock watering fluoride standard, and the assessment and evaluation of the proposed fluoride criteria for supporting continual use of the river for livestock watering purposes was previously discussed above. As such, the proposed fluoride water quality criteria of 2.6 mg/l will be protective of existing and any future wildlife beneficial uses.

Industrial Supply

Primary industrial users of the Muddy River are Nevada Power Company (NPC) in the upper Moapa Valley and silica sand processing operations in the lower valley. The NPC diverts water from the Muddy River, upstream from the Warm Springs road bridge, for industrial use at the Reid Gardner power station. Water from the Muddy River is supplied to the silica sand processing operations via the Muddy Valley Irrigation Company canal system in the lower Moapa Valley. Fluoride limits have been recommended when water is used for industrial purposes involving food manufacture and packaging and beverage production. The current industrial uses of the Muddy River do not fall under either of these categories, and therefore, the proposed fluoride criteria will support continual use of the river water for industrial supply purposes.

13.0 Fluoride Water Quality Criteria For the Lower Muddy Reach

A different fluoride water quality criteria is proposed for the lower reach. The lower Muddy River channel primarily conveys irrigation return flows and tail water from agricultural operations in the Logandale and Overton areas (see Figure 5). In essence, the river channel serves as a drainage feature for subsurface flows from agricultural fields and for tail water exiting the network of canal and lateral drains in the lower Moapa Valley (Bureau of Reclamation 1962). As such, the chemistry of the water in the lower Muddy River channel is different from the upper Muddy River water which is removed from the river channel at the Wells Siding diversion.

The only withdrawal of water from the lower reach is at the Overton Wildlife Management Area. A diversion dam at the upper end of the management area allows the project to acquire water from the lower Muddy River. This water is used for filling ponds, flooding marshes, and raising crops which provide habitat, forage, and shelter for migratory waterfowl, other bird species, and wildlife. Crop plants which are grown for habitat and forage are alkali bulrush and clover.

Development and operation of the Overton Wildlife Management Area has relied on irrigation return flows taken from the Muddy River as the water supply source (Bureau of Reclamation 1962). The quality of the water that reaches the wildlife management area diversion structure varies from fair to poor depending on the upstream irrigation season. Available historical water sampling data showed that fluoride levels in the lower Muddy River measured at the Overton Wildlife Area over a 9-month period from July 7, 1965 to March 23, 1966, ranged from about 2 mg/l to almost 5 mg/l (see Table 9).

13.1 Derivation of Proposed Fluoride Water Quality Criteria For the Lower Reach

Water chemistry samples have been collected from the lower Muddy River by an outside entity at Lewis Avenue in Overton which is approximately 0.5 miles upstream of the Overton Wildlife Management Area's diversion dam (see Figure 5). Fluoride levels in the samples collected on a monthly basis over a 5-year period (June 2002 to November 2007) from the lower reach at this location are shown in Table 9. Fluoride levels ranged from less than 1.0 mg/l to 4.0 mg/l with an average concentration of approximately 3 mg/l. The corresponding 95th percentile value of the measured fluoride levels was 3.6 mg/l.

The 95th percentile of measured fluoride concentrations is proposed as the water quality criteria for the lower reach. The proposed criteria of 3.6 mg/l fluoride (total recoverable) is based on the measured levels in the lower reach and reflects the evaporative concentration of fluoride in the lower river from normal agricultural practices.

Table 9. Fluoride Levels Measured in Muddy River at Lewis Ave. (Jun 2002 – November 2007).

Date	Fluoride (mg/l)	Date	Fluoride (mg/l)
6/20/2002	3.45	3/24/2005	2.8
7/17/2002	3.47	4/21/2005	2.9
8/14/2002	4.03	5/19/2005	3.0
9/19/2002	3.6	6/22/2005	4.0
10/16/2002	3.25	7/27/2005	2.9
11/13/2002	3.2	8/31/2005	2.6
12/18/2002	3.36	9/21/2005	2.9
1/15/2003	3.32	10/19/2005	1.1
2/19/2003	3.04	11/30/2005	0.71
3/19/2003	3.3	12/28/2005	0.56
4/17/2003	2.82	1/24/2006	1.7
5/14/2003	2.94	2/22/2006	3.7
6/18/2003	3.38	3/22/2006	0.94
7/16/2003	3.00	4/20/2006	2.2
8/13/2003	2.8	5/17/2006	3.4
9/17/2003	3.4	6/21/2006	3.0
10/15/2003	3.4	7/26/2006	2.2
11/19/2003	3.4	8/16/2006	2.6
12/17/2003	2.9	9/20/2006	2.6
1/14/2004	3.8	10/18/2006	2.8
2/19/2004	3.6	11/15/2006	0.53
3/25/2004	3.1	12/20/2006	3.4
4/28/2004	2.7	1/24/2007	2.7
5/18/2004	2.9	2/14/2007	3.0
6/16/2004	3.1	3/21/2007	2.9
7/15/2004	3.7	4/25/2007	2.2
8/25/2004	3.0	5/23/2007	2.8
9/22/2004	2.8	6/27/2007	2.7
10/21/2004	3.0	7/25/2007	2.6
11/17/2004	3.1	8/23/2007	3.3
12/22/2004	3.1	9/26/2007	1.5
1/27/2005	2.7	10/24/2007	1.1
2/23/2005	0.94	11/14/2007	1.2
Minimum Fluoride (mg/l)			0.5
Maximum Fluoride (mg/l)			4.0
Average Fluoride (mg/l)			2.8
95th Percentile Fluoride (mg/l)			3.6

Source: Southern Nevada Water Authority
Chemical Monitoring Results from Muddy River

The following rough mass balance calculation is presented to illustrate that the higher downstream fluoride concentrations are attributable to evaporative concentration effects and not from controllable sources. A comparison is made between the average fluoride loads calculated in the upper reach at Glendale and in the lower reach at Lewis Avenue. Average fluoride levels measured at the Glendale Bridge and at Lewis Avenue and average flows recorded at the Glendale and Lewis gaging stations are used to calculate average loads [(Avg. Flow) (Avg. Fluoride Level) = Avg. Fluoride Load].

Average Flow Glendale Gage (USGS Records): 42 cfs ($102.8*10^6$ liters/day)
Average Fluoride Level at Glendale Bridge (2004-2007): 2.4 mg/l
Average Fluoride Load at Glendale: 246,720 grams/day

Average Flow Lewis Ave. Gage (USGS Records): 13 cfs ($31.8*10^6$ liters/day)
Average Fluoride Level at Lewis Ave. (2002-2007): 2.8 mg/l
Average Fluoride Load at Lewis Ave: 89,040 grams/day

Between the Glendale gage and the Lewis Avenue gage, the volume of flow decreases by 70 percent due to irrigation diversion. This reduction in flow and corresponding concentration of salt values results in the average fluoride level in the lower reach being almost 1.2 times higher than in the upper reach. The fluoride load calculated in the lower reach to be approximately 64 percent less than in the upper reach indicates that no other sources contribute a significant amount of fluoride to the lower reach.

13.2 Evaluation of The Proposed Fluoride Water Quality Criteria For the Lower Reach

The only point of diversion and use of the Muddy River below Wells Siding is the Overton Wildlife Management Area. For the past 50-plus years, this facility has used the irrigation return flows in the lower Muddy River as the source of water to operate the facility. The quality of the irrigation return flow water has been fair to poor, as would be expected, but has been used to provide habitat and forage to migratory waterfowl, bird species, and wildlife. The elevated fluoride values of the return flows in the river channel reaching the wildlife management area has not been an issue in using the water to fill the ponds and marshes on the property, or to grow crops for shelter and forage.

The fluoride water quality criteria of 3.6 mg/l reflects the existing water quality of the lower reach and will not impede current and future uses of this water on the wildlife management area. The water obtained from the lower Muddy River channel is not used on the wildlife management area for livestock drinking water or for raising agricultural crops for commercial production. The USEPA has recommended water quality standards to protect both of these uses when the water is used for such (USEPA 1972). The problems associated with the current fluoride irrigation and livestock watering standards have been previously discussed. A water quality standard to protect wildlife, in particular, waterfowl, from possible effects from fluoride has not been developed by the USEPA nor has an interim threshold value been recommended by the USFWS.

14.0 Impact of High Fluoride Levels in Muddy River to Lake Mead

During the Bureau of Reclamation investigation conducted in the 1960s to evaluate the feasibility of increasing the agricultural potential of the Moapa Valley, water samples were collected from the Overton Arm of Lake Mead. The fluoride concentrations in the samples collected over a nine-month period from July 1965 to March 1996 are shown in Table 10 (Bureau of Reclamation 1971).

Table 10. Fluoride Levels in Samples Taken From Lake Mead (Overton Arm); July 1965 to March 1965 (Bureau of Reclamation 1971).

Date	No. Samples Taken [1]	Fluoride Range (as mg/l)
July 21, 1965	5	0.37 to 0.37
August 4, 1965	6	0.51 to 0.51
August 18, 1965	5	0.26 to 0.40
September 1, 1965	5	0.53 to 0.72
December 21, 1965	2	1.0 to 1.0

[1] Samples collected approximately one mile south of Overton Beach and 1,000-feet offshore. Samples taken at surface and at 10-foot intervals to lake bottom, except December 21, 1965 (samples taken at surface and 40-foot depth).

The fluoride levels measured in the Overton Arm of Lake Mead by the Bureau of Reclamation was 1 mg/l or less, even though a significantly higher concentration of fluoride was present in the Muddy River flow to the lake (see Table 9).

More recent samples have been collected in the Overton Arm of Lake Mead by the Bureau of Reclamation. Monthly water chemistry samples (August 2007 to May 2008) have been taken at various distances into the Overton Arm from the confluence of the Muddy River with Lake Mead. Fluoride levels ranged from 0.33 mg/l to 0.95 mg/l with an average of 0.41 mg/l. (Source: Southern Nevada Water Authority, Chemical Monitoring Results from Muddy River)

The historic and more recent fluoride water chemistry samples collected in the Overton Arm of Lake Mead show that there is not a discernable effect to the water quality in this section of the lake. Although fluoride levels are high in the Muddy River discharge to the lake, as the river water mixes with the lake water as well as water from the Virgin River within the Overton bay, the resulting fluoride lake levels are less than the 1.0 mg/l irrigation water quality criteria which is applicable to Lake Mead.

15.0 Boron Irrigation Water Quality Criteria For the Lower Reach

The current promulgated Nevada water quality criteria for boron are 0.75 mg/l in irrigation waters and 5.0 mg/l in livestock drinking waters (NAC 445A.144). Both of these values are from USEPA's Blue Book of Water Quality Criteria (USEPA 1972). The information presented in the Blue Book regarding boron levels in irrigation waters showed that plants vary in their tolerance to boron. Although boron is essential for all plant growth, if present in amounts appreciably greater than needed, it becomes toxic. Certain citrus plants were found to be sensitive to boron at concentrations of less than 1.0 mg/l in irrigation water, while more tolerant crops, such as alfalfa, tomato, and asparagus, had higher boron tolerance limits (Maas 1984).

The 0.75 mg/l boron threshold value was established to protect sensitive crops, though the USEPA also recommended a maximum concentration of 1 mg/l to 2 mg/l boron for non-sensitive plants. The USEPA re-issued the 0.75 mg/l value in the Gold Book of recommended water quality criteria without providing any new supporting citations or data (USEPA 1986).

Boron tolerance limits for some common agricultural crops are shown in Table 11. The information presented in the table provides a range of threshold values based on the tolerance of different plant species to boron (Maas 1990).

Table 11. Boron Tolerance Limits for Agricultural Crops.

	Threshold (Boron, mg/l)
Very Sensitive	
Lemon, Blackberry	<0.5
Sensitive	
Avocado, Grapefruit, Orange, Apricot. Peach, Cherry, Plum, Fig, Grape, Walnut, Pecan, Onion	0.5 – 0.75
Garlic, Sweet Potato, Wheat, Bean, Sunflower, Strawberry, Artichoke, Peanut	0.75 – 1.0
Moderately Sensitive	
Broccoli, Red Peppers, Pea, Carrot, Radish, Potato, Cucumber, Lettuce	1.0 – 2.0
Moderately Tolerant	
Cabbage, Turnip, Kentucky Bluegrass, Barley Oats, Corn, Artichoke, Tobacco, Mustard, Clover (sweet), Squash, Cauliflower	2.0 – 4.0
Tolerant	
Alfalfa, Parsley, Red Sugar Beet, Tomato	4.0 – 6.0
Very Tolerant	
Sorghum, Cotton, Celery, Asparagus	6.0 – 15.0

Adoption of a single boron irrigation criteria to protect all crops results in a very low value, due to the low tolerance of sensitive species to boron. As shown above in the table, a boron irrigation standard of 0.75 mg/l is primarily protective of fruit and nut crops. Typical crop species grown for forage such as barley, grass and alfalfa hay have boron tolerance levels greater than 0.75 mg/l.

The recommended maximum allowable level of boron in livestock drinking water of 5.0 mg/l was based on the maximum amount of this element found in 1,546 samples of river and lake waters sampled in various parts of the United States (USEPA 1972). Boron is required by plants but it has no known function in animals. A study published in 1977 reported that yearling Hereford heifers exposed to 150 and 300 mg/l boron in drinking water had reduced hay intake and corresponding weight loss (Green and Weeth 1977). Although limited, available toxicological information reported in the scientific literature indicated that boron had a low toxicity to cattle, but to offer a large margin of safety, a tolerance level of 5.0 mg/l of boron in livestock drinking water was recommended by the USEPA in the Blue Book (USEPA 1972). Information on the effects of boron in the drinking waters of wildlife is limited. The United States Fish and Wildlife Service (USFWS) recommended that until more data becomes available, the livestock drinking water threshold of 5.0 mg/l also be used to protect wildlife from adverse effects of boron (Eisler 1990).

15.1 Proposed Boron Irrigation Water Quality Criteria For the Lower Reach

A boron irrigation water quality criteria of 2.0 mg/l is proposed for the lower reach which is the lower value of the range of boron tolerance limits for moderately tolerant agricultural crops (see Table 11). This proposed boron threshold is a more appropriate protective value based on the crops that are irrigated with water from the lowermost reach of the Muddy River. The proposed boron criteria of 2 mg/l is still less than the protective value of 5.0 mg/l boron that has been recommended by default for wildlife propagation.

NDEP-BWQP is not proposing to revise the existing boron irrigation water quality criteria of 0.75 mg/l on the upper and middle reaches of the Muddy River. Retaining the existing irrigation criteria will provide a level of protection for any sensitive plants/crops that may be grown in the lower Moapa Valley. Irrigation water used in the Logandale and Overton areas is diverted upstream and not directly withdrawn from the lower Muddy River.

15.2 Evaluation of Proposed Boron Irrigation Water Quality Criteria For the Lower Reach

For the lower reach, a boron irrigation water quality criteria set to protect sensitive crops is inappropriate. The only irrigation use of water from the lower river channel is at the Overton Wildlife Management refuge to grow crops for wildlife forage, habitat, and shelter. The primary plants grown for these purposes are alkali bulrush and clover which are not considered plant species that are sensitive to boron and consequently, their growth would not be affected by high levels of boron in the water used for irrigation. The Muddy River water diverted to the Overton Wildlife Management Area is not used for crop production or used in raising livestock.

The water quality conditions in the lower Muddy River – high silt and dissolved salt content and high water temperatures - and low flows during the summer limit the potential for this stretch of the river to support a desirable sport fishery. Eisler in his review of the ecological and toxicological aspects of boron in the environment recommended proposed boron criteria for protection of aquatic organisms. Non hazardous levels in water ranged from 1 mg/l boron to 5 mg/l boron for fish, oysters, and aquatic plants. Reported "safe" boron levels in water for largemouth bass and bluegill were less than 30 mg/l and less than 33 mg/l, respectively. For protection of sensitive species from adverse effects, a range of 10-12 mg/l boron was recommended (Eisler 1990). The proposed boron water quality criteria of 2.0 mg/l for the lower reach is below the aforementioned recommended threshold values for warm water and sensitive aquatic life species, and should not impact any aquatic life that may migrate into this section of the river from Lake Mead during high water years.

The boron levels measured in the lower reach at Overton and Lewis Avenue are shown in Figures 11a and 11b, respectively.

Figure 11a
Boron Levels in Lower Reach at Overton

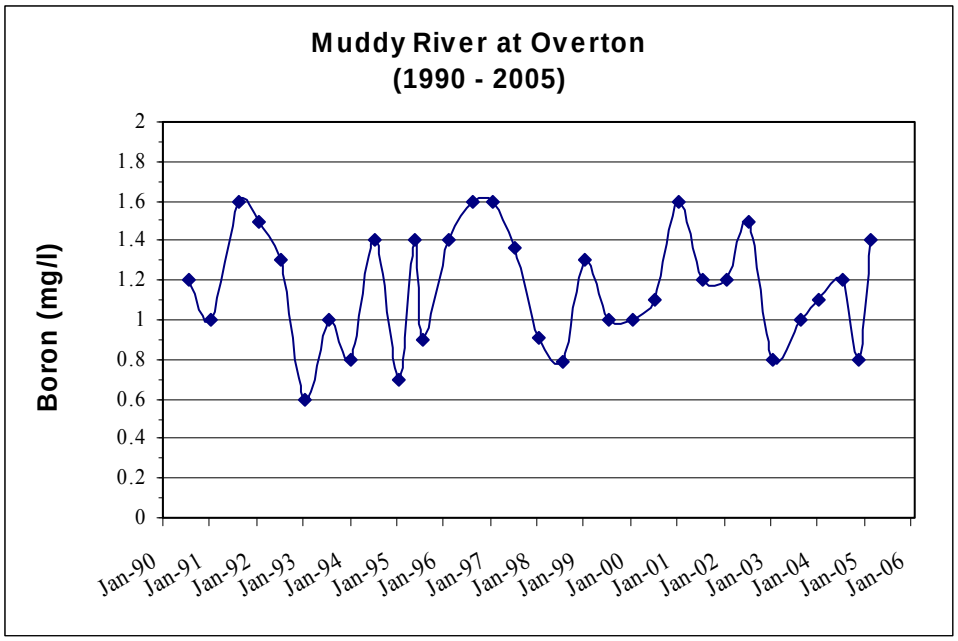
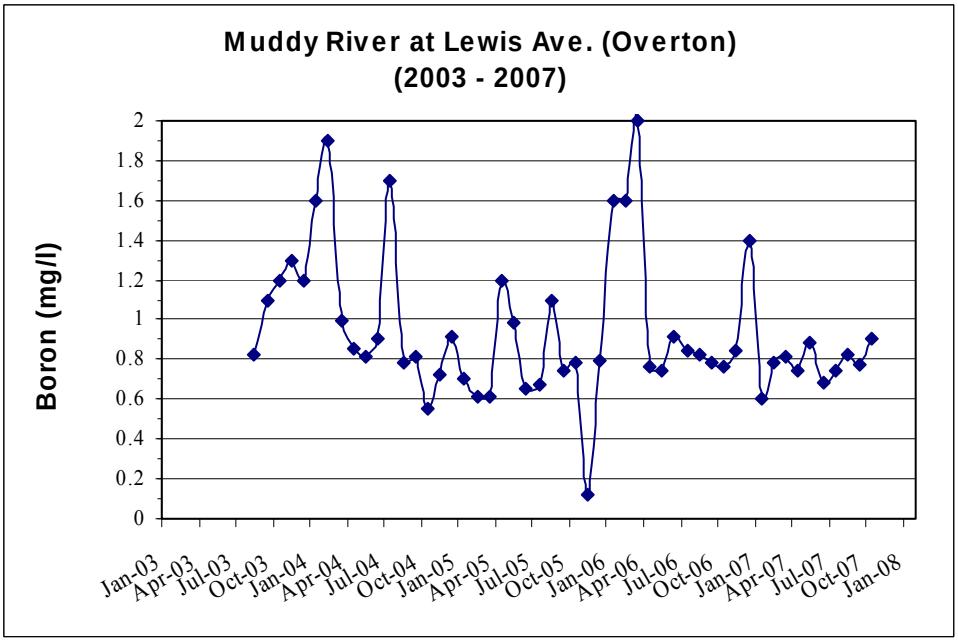


Figure 11b
Boron Levels in Lower Reach at Lewis Ave.



Boron levels measured in the lower reach at the Overton monitoring site have generally been above the 0.75 mg/l boron threshold for sensitive plants but below the proposed water quality criteria of 2.0 mg/l for the lower section of the river.

The boron levels measured in monthly samples taken at Lewis Ave. in Overton over a 5 year period by an outside entity are shown in Figure 11b (Source: Southern Nevada Water Authority, Chemical Monitoring Results from Muddy River). The Lewis Ave. monitoring site is approximately 0.5 miles upstream of the NDOW diversion for the wildlife refuge. Boron levels in 76 percent of the samples collected over the 5-year period were greater than the current state-wide irrigation criteria of 0.75 mg/l.

A rough mass balance calculation is presented below to evaluate average boron loads in the upper and lower sections of the river. Average boron levels measured at the Glendale Bridge and at Lewis Ave. and average flows recorded at the Glendale and Lewis Ave. gaging stations are used [(Avg. Flow) (Avg. Fluoride Level) = Avg. Fluoride Load].

Average Flow Glendale Gage (USGS Records): 42 cfs ($102.8*10^6$ liters/day)
Average Boron Level at Glendale Bridge (2002-2007): 0.45 mg/l
Average Boron Load at Glendale: 46,260 grams/day

Average Flow Lewis Ave. Gage (USGS Records): 13 cfs ($31.8*10^6$ liters/day)
Average Boron at Lewis Ave. (2002-2007): 0.94 mg/l
Average Boron Load at Lewis Ave: 29,892 grams/day

The rough calculations indicate that the higher boron levels measured in a downstream direction are related to decreased flows and evaporative concentration effects rather than from increased boron inputs to the lower reach. The average boron load in the lower reach is approximately 35 percent less than in the upper reach even though the average boron level in the lower section of the river is twice as high.

16.0 Impact of High Boron Levels in Muddy River to Lake Mead

During the Bureau of Reclamation's assessment of the existing and the future agricultural potential of the upper and lower Moapa Valleys, water samples were taken from the Overton Arm of Lake Mead in the mid-1960s (Bureau of Reclamation 1972). The boron levels in Lake Mead water samples that were collected over the time period from July 1965 to January 1966 are shown in Table 12. The boron levels in the samples ranged from 0.12 mg/l to 0.46 mg/l with an average value of 0.24 mg/l.

Table 12. Boron Levels in Samples Taken From Lake Mead (Overton Arm); July 1965 to January 1966 (Bureau of Reclamation 1971).

Date	No. Samples Taken [(1)]	Boron Range (as mg/l)
July 21, 1965	5	0.22 to 0.46
August 4, 1965	6	0.12 to 0.22
August 18, 1965	5	0.22 to 0.36
September 1, 1965	5	0.0 to 0.36
January 25, 1966	2	0.22 to 0.22

[(1)] Samples collected approximately one mile south of Overton Beach and 1,000-feet offshore. Samples taken at surface and at 10-foot intervals to lake bottom, except December 21, 1965 and January 25, 1966 (samples taken at surface and 40-foot depth).

A continuous monitoring program has recently been initiated by the Bureau of Reclamation in the Overton Arm of Lake Mead. This monitoring program includes collecting water chemistry samples at various distances into the Overton Arm from the confluence of the Muddy River with Lake Mead. Preliminary chemistry results from the lake samples collected from August 2007 to May 2008 showed that boron levels in the samples ranged from 0.13 mg/l to 0.54 mg/l with an average of 0.21 mg/l. (Source: Southern Nevada Water Authority, Chemical Monitoring Results from Muddy River) Although these results are limited, the recently measured boron levels in the lake fall within the range of boron levels measured in the Overton Arm of Lake Mead during the mid-1960s by the Bureau of Reclamation. The boron levels have been below the threshold value of 0.75 mg/l which is the current boron irrigation water quality criteria for Lake Mead.

17.0 Bowman Reservoir

Bowman Reservoir is a Class C water and the beneficial uses and water quality criteria in NAC 445A.126 apply to this waterbody. It is proposed to make Bowman Reservoir a designated waterbody thereby creating a table of water quality standards specific to Bowman Reservoir. The existing water quality criteria contained in NAC 445A.126 would be incorporated into the table of water quality standards for the reservoir with the following additions:

- The proposed fluoride water quality criteria of 2.6 mg/l for the upper and middle reaches of the Muddy River is also proposed for Bowman Reservoir. At the Wells Siding diversion, which is the lower end of the middle reach, Muddy River water is diverted to Bowman Reservoir for subsequent agricultural use in the lower Moapa Valley.

- Due to its association with the Muddy River, Bowman Reservoir is also considered a water of the Colorado River Basin. As such, the Colorado River Salinity Standards (total dissolved solids) specified in NAC 445A.143 which are assigned to the Muddy River would also be applicable to Bowman Reservoir.

18.0 References

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