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Risk and Consequence Analysis Focused on Biota Transfers Potentially Associated with Surface Water Diversions Between the Missouri River and Red River Basins

Written, edited, and compiled by Greg Linder, Ed Little, Bruce Peacock, Heather Goeddeke, Lynne Johnson, and Chad Vishy

Executive Summary

Under the auspices of the Dakota Water Resources Act (DWRA) of 2000, the Secretary of the Interior has been directed to conduct a comprehensive study of the water quality and quantity needs of the Red River Valley and the options for meeting those needs. As such, the Bureau of Reclamation (Reclamation) requested technical support from the U.S. Geological Survey (USGS) Columbia Environmental Research Center (CERC) for an evaluation of the risks and economic consequences of biota transfers potentially associated with interbasin water transfers that might occur between the Upper Missouri River and the Red River of the North (Red River) basins. This project report summarizes the technical findings of CERC staff and their Department of the Interior (DOI) partners in the National Park Service (NPS) with respect to these concerns regarding interbasin biota transfer. This technical report consists of six sections with accompanying appendices. Section 1 provides a brief overview of the project and the historic context for this evaluation focused on potential biota transfers. Section 2 summarizes the technical tools applied to the analysis of risks and economic consequences that are summarized in Section 3. Section 4 characterizes the risks potentially associated with biota transfers directly resulting from interbasin water transfers and competing pathways, while the economic consequences that are derivatives of those risks are considered in Section 5. Section 6 presents a summary of risks and economic consequences detailed in the report. A series of appendices provides detailed technical materials that support the analysis of risks, economic consequences, and their attendant uncertainties.

Section 1 provides a brief overview of the project, including a cursory summary of the history of the "Garrison Diversion" and how that history relates to this work focused on the analysis of risks and consequences potentially associated with interbasin biota transfers. The present study was initiated under the auspices of the Dakota Water Resources Act (DWRA) of 2000, which directed the Secretary of the Interior to conduct a comprehensive study of the water quality and quantity needs of the Red River Valley and the options for meeting those needs. As such, the Bureau of Reclamation (Reclamation) requested technical support from the U.S. Geological Survey (USGS) Columbia Environmental Research Center (CERC) for an evaluation of the risks and economic consequences of biota transfers potentially associated with interbasin water transfers that might occur between the Upper Missouri River and the Red River of the North (Red River) basins. Pursuant to guidance from National Academy of Sciences, National Invasive Species Council, regulatory agencies (e.g., US Environmental Protection Agency), and nongovernmental organizations such as The Nature Conservancy and awardees of Sea Grant program support, USGS/CERC entered into an iterative risk-assessment process with stakeholders interested in the biota transfer issue. Section 1 summarizes the implementation of the stepwise risk assessment process, with the primary outcomes of the section detailed in the problem formulation phase of the USGS technical support project. Outcomes of problem formulation were focused on identifying biota of concern (Table ES1) and related issues associated with interbasin biota transfers, pathways potentially linking Missouri River and Red River basins, and the potential confounding factors that might influence the interpretation of cause-effect relationships predicated on biota transfers, if these events did occur in the future.

Section 2 summarizes the tools applied to this desk-top analysis of risks associated with interbasin biota transfers regardless of the roles played by potential diversions of Missouri River source waters to Red River basin. Predicated on the outcomes of problem formulation, e.g., conceptual models, measurement and assessment endpoints were characterized and linked to the primary tool–habitat equivalency analysis–for evaluating consequences. Terminology critical to the evaluation of risks of biota transfer was characterized, including project-specific definitions for "introduction," "native," "alien," and "invasive." Data-mining techniques were applied to open literature searches initiated for compiling existing data and information on biota of concern. Outcomes of those searches are detailed and summarized. Potential pathways directly associated with engineered interbasin water diversions were considered as one of many competing pathways linked to human device(s) or natural events (i.e., those not linked to anthropogenic activities). A

Table ES1. Biota of concern identified for analysis focused on biota transfers from Upper Missouri River basin to Red River basin.

Microorganisms and Infectious Diseases	Aquatic invertebrates: Mollusks
Enteric redmouth Infectious hemtopoietic necrosis virus (IHNV) *Escherichia coli* (various serotypes)* *Legionella* spp.* *Salmonella* spp. *(*including, but not limited, to *S. typhi, S. typhmurium,* other *Salmonella* serotypes, and other waterborne infectious diseases*)** **Protozoa and Myxozoa** *Myxosoma cerebralis (Myxobolus cerebralis)* *Polypodium hydriforme* *Cryptosporidium parvum** *Giardia lamblia** **Cyanobacteria** *Anabaena flos-aquae** *Microcystis aeruginosa** *Aphanizomenon flos-aquae** **Vascular plants** Hydrilla (*Hydrilla verticillata*) Eurasian water-milfoil (*Myriophyllum spicatum*) Water hyacinth (*Eichhornia crassipes*) Purple loosestrife (*Lythrum salicaria*) Salt cedar (*Tamarix* spp.; at least eight species have been listed as introduced into the U.S. and Canada)	Zebra mussel (*Dreissena polymorpha*) Asian clam (*Corbicula fluminea*) New Zealand mudsnail (*Potamopyrgus antipodarum*) **Aquatic invertebrates: Crustaceans** Spiny water flea (*Bythotrephes cederstroemi*) **Aquatic vertebrates: Fishes** Gizzard shad (*Dorosoma cepedianum*) Rainbow smelt (*Osmerus mordax*) Paddlefish (*Polyodon spathula*) "Asian carp"† Pallid sturgeon (*Scaphirhynchus albus*) Utah chub (*Gila atraria*) Zander (*Sander* [*Stizostedion*] *lucioperca*) **Invasive biota associated with sludge disposal and indirect pathways associated with interbasin water transfers, including:** Potential transfer of plant and disease organisms (plant, wildlife, and human) Potential transfer of genetically manipulated organisms Potential biota transfers derived from sludge disposal

* Reclamation and Technical Team acknowledged the potential for interbasin water diversions to influence existing local populations in Missouri River and Red River basins. Species that currently occupy both basins were included on the list of biota of concern, since their potential interbasin water transfer may have adverse impact on fish and wildlife or human health.

† Composite grouping of species of carp originally entering North America from source areas in Asia; species include bighead carp (*Hypophthalmichthys* [*Aristichthys*] *nobilis*), silver carp (*Hypophthalmichthys molitrix*), and black carp (*Mylopharyngodon piceus*).

series of nested fault-probability trees (FPTs) were built to graphically illustrate the biota transfer process potentially captured by interbasin water diversions and competing pathways linked to anthropogenic or natural (not aided by human devices or activity) processes. Tools applied to the analysis of risks are characterized, including categorical and spatiotemporal tools employing traditional dot maps to characterize current distributions of biota of concern, and genetic algorithms focused on ecological-niche models to project potential distributions for these species.

Section 3 summarizes the outcomes of the risk analysis completed for the biota transfer project. The analysis of risks associated with potential biota transfers yielded multiple, complimentary outcomes stemming from the range of analytical tools applied to the evaluation of risks. Outcomes of the analysis of risks resulted from qualitative evaluations, largely based on narrative analyses dependent upon existing information on past and current distributions and life-history attributes potentially associated with future species incursions that might result in successful invasions or shifts in metapopulations. Quantitative evaluations based on categorical analysis considered life-history attributes and assigned numerical scores to each biota of concern, yielding a priority list of species likely to be problematic, if biota transfers occurred in the future. Outcomes of categorical analysis suggested that potential transfers of species already occurring in both Missouri River and Red River basins may occur in the future, since existing multiple competing pathways may link these basins regardless of whether designed water diversions are realized. Whether transfers of species already occurring in both basins would be associated with a measurable shift in metapopulations is unclear, given the relatively sparse data available for the analysis. While georeferenced distribution data were not sufficient for characterizing potential species distributions for all biota of concern, when sufficient data were available, spatiotemporal analysis considered biota transfers and prediction of species distributions through an ecological-niche based model algorithm. Illustrative projections of potential distributions for representative aquatic nuisance species, such as Zebra mussel, New Zealand mudsnail and riparian plants, such as tamarisk, were incorporated into the quantitative analysis as available and suggested that some biota of concern may become invasive in the future, although these species invasions are not uniquely linked to interbasin water diversion, because of multiple pathways available for incursion.

Section 4 focuses on the synthesis and integration of results from risk analysis which is the primary output for risk characterization. The analysis of risks supports management decisions regarding water resources in the northern Great Plains. When completed in parallel with an analysis of uncertainties associated with those risks, risk managers are better positioned to develop and implement resource management practices, e.g., technically evaluate alternatives as

management options to reduce risks (see Wittenberg and Cock 2001; Downes et al. 2002). Characterizing risks associated with a specific management activity such as water diversions moves us toward weighing potential consequences of an event—here, a species invasion or shift in metapopulation dynamics of an organism—relative to a specific pathway and designing and implementing options to address those risks and associated consequences. The integration of ecological consequences potentially linked to future invasions or shifts in metapopluations was considered relative to the adverse effects that organisms might cause, and served as our "risk input" for subsequent economic analysis. Economic consequences were focused on biological and ecological effects, and in Section 5 these associated economic outcomes have been captured through an evaluation that focused on habitat equivalency analysis and collateral measures of economic effects. While categorical and quantitative estimates of risk were developed in Section 3 and are characterized with respect to their attendant uncertainties in this section, a narrative analysis of pathways and their potential risk derivatives has also been considered, with a particular focus on biota of concern lacking data sufficient to more quantitative estimates of risks.

Overall, risks of biota transfers varied across representative species of concern and followed a priority risk ranking as

Fishes << Aquatic invertebrates $\leq$ Aquatic and terrestrial-wetland plants < Waterborne disease agents $\leq$ Cyanobacteria

suggesting interbasin transfers of fishes would be least likely to occur; hence, risks would be very low. In contrast, transfers of waterborne disease agents and cyanobacteria (or their toxins) would be associated with greater risks, particularly if control systems were not incorporated into water diversion processes and infrastructure. Risks were greatest when interbasin water diversions were envisioned as being implemented via open conveyance and only slightly reduced if untreated waters were piped from exporting to importing basin. Greatest risk reduction was achieved when source waters were treated (e.g., using combined control technologies such as conventional water treatment and pressure-driven membrane filtration) within the exporting basin then transferred via closed conveyance (e.g., piped transfer) to importing basin.

Section 5 summarizes economic analyses that estimated the potential consequences associated with interbasin water transfers between the Upper Missouri River and Red River basins. Two economic approaches were used to estimate these consequences. Habitat equivalency analysis was used to estimate consequences throughout the assessment area including the Red River and Lake Winnipeg. That analysis indicated risk consequences ranging from 0.6 to 3.1

river-miles of offsetting restoration on the Red River and from 1.9 to 27,750 acres of offsetting restoration on Lake Winnipeg. While those results suggest potentially significant consequences for Lake Winnipeg, their interpretation depends on the feasibility and availability of appropriate restoration measures.

Since the feasibility and availability of those restoration measures is not clear at this time, a second economic approach was used to focus the consequence analysis on Lake Winnipeg. Regional economic impact analysis was used to estimate the impacts on output (sales revenue) and employment in the Lake Winnipeg commercial fishery. The invasion scenarios with the largest consequences (slow and fast invasions given a jump dispersal event) indicated a total expected present value between $33,000 and $136,000 in direct and indirect output impacts for all Canadian provinces. All other invasion scenarios indicated smaller output impacts. Expected employment impacts in the very high-risk category (i.e., certainty) reach 331 full-time equivalent (FTE) jobs. The average expected employment impacts weighted by the percent outcomes of respective risk categories is 0 FTE for all invasion scenarios.

Given the quantitative results from the habitat equivalency analysis and the regional economic impact analysis, the following three conclusions can be drawn. First, the overall results are sensitive to the distribution of probabilistic outcomes from the risk characterization. Consequence levels for the individual risk categories vary substantially. That variance reflects the different probabilities of successful invasion. A different distribution of probabilistic outcomes would change the weighted averages of the consequence levels. Therefore, this consequence analysis is sensitive to the results of the risk analysis. In this particular case, the weighted average consequences are heavily weighted toward the lowest risk category (87% of outcomes in the very low-risk category). A distribution more heavily weighted toward the higher-risk categories would yield substantially higher-weighted averages of consequences.

The second conclusion of this consequence analysis is that the speed of invasion significantly affects the quantitative results. As many as four orders of magnitude difference in offsetting restoration levels exist between the two invasions' speeds assumed in this analysis, and one order of magnitude difference is captured by output impacts. A much more detailed analysis would match individually estimated invasion speeds to respective organisms and then aggregate the indicated consequence levels over the species of concern. However, the information regarding species-specific invasion speeds was not available to conduct that level of analysis. Therefore, this

analysis indicates not only the significance of this analytic factor but also the need for additional research in this area.

This consequence analysis also concludes that the anticipated distribution of the method and number of dispersal events substantially affects the quantitative results. This analysis considered only a limited set of potential dispersal scenarios. No information was available to inform the distribution of these scenarios to include in the analysis. However, the limited number of potential dispersal scenarios analyzed here indicated as many as four orders of magnitude difference in offsetting restoration levels between them. Similar to the conclusion regarding the speed of biotic invasion, this analysis indicates a significant analytic factor and a need for further research.

In Section 6, technical findings are summarized. In this report the analysis of risks and consequences are predicated on the assumption that water from the Missouri River will be transferred to the Red River basin. At times policy perspectives on water resource management are in conflict, e.g., precautionary measures vary with respect to implementation when encountering contrary views held with equal conviction. Resolution of these conflicting views, or rather the interpretation of how these policies should be implemented, is not a technical problem even if technical solutions are sought. This technical report can only hope to bring an analytical perspective to the discussion of risks and consequences associated with biota transfers potentially occurring consequent to an interbasin water diversion. If the water diversion is realized, the risks of biota transfers range from “highly likely to occur” to “highly unlikely to occur,” depending on how the diversion is realized. Economic consequences match these technical findings focused on risk.