

# [***ARTICLE: THE VIEW FROM THE WITNESS STAND: PRESENTATION OF SCIENTIFIC EVIDENCE AND OPPORTUNITIES FOR IMPROVEMENT IN COLORADO'S WATER COURTS IN THE NEXT FIFTY YEARS***](https://advance.lexis.com/api/document?collection=analytical-materials&id=urn:contentItem:5XBK-6JB1-F7VM-S433-00000-00&context=1516831)

Spring, 2019

**Reporter**

22 U. Denv. Water L. Rev. 623 \*

**Length:** 31414 words

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**Highlight**

Reliance on scientific evidence in ***Colorado***'s water courts has increased substantially over the past fifty years due to: advances in scientific understanding of groundwater and the interaction between groundwater and surface water; improved technology including computer models; greater specialization of expertise; more available data than in the years prior to adoption of the Water Right Determination and Administration Act of 1969 ("the 1969 Act"); and increased competition for water. These developments have led to an increased focus in ***Colorado***'s water courts, as with courts nationwide, on the reliability of scientific evidence and expert testimony. Expert testimony in ***Colorado***'s water courts has improved over time. In 2009, the ***Colorado*** Supreme Court amended the Water Court Rules, including Rule 11 which governs the use of experts in ***Colorado***'s water courts. The 2009 Rules changed for the better how testifying experts work with each other, develop disclosures, and present testimony. However, there are still issues with expert testimony in water courts that must be better addressed, including adversarial bias among experts and the need for continuing education for testifying experts. Rule changes and better continuing education, as detailed in section 6, will help minimize pitfalls such as adversarial bias and "gaming of the system," and will improve efficiency and accuracy of water court decisions, ultimately serving the public interest.

**Text**

**[\*624]**

I. Introduction

*"(Life) is a tale, told by an idiot, full of sound and fury, signifying nothing."* [[2]](#footnote-3)2

Judge Robert Ogburn introduced his decision in the contentious case *In re Water Rights Application* with the above quote from William Shakespeare as a wry summation of the lengths the parties in the case went to bludgeon and discredit each other. [[3]](#footnote-4)3The case, which involved a claim to San Luis Valley groundwater, resulted in a "battle of the models" that involved hundreds of hours of highly adversarial expert testimony and allegations of bias among the experts. [[4]](#footnote-5)4Despite millions of dollars spent litigating a 200,000 annual acre-foot claim, [[5]](#footnote-6)5not one single foot of new subsurface drilling data was developed, and not one single new aquifer test was performed. [[6]](#footnote-7)6

*In re Water Rights Application* was one of the first large ***Colorado*** water cases that hinged on expert testimony concerning models of groundwater and surface water interacting in a highly complex hydrologic system. The need for specialized expert testimony in the case and others like it stemmed from the 1969 Act, which had codified decades of water law practice and policy in the state. [[7]](#footnote-8)7Additionally, the 1969 Act regulated the use of groundwater for the first time by acknowledging the scientifically valid integration of surface water and groundwater into a single, conjunctively used resource under a policy of "optimum utilization" as part of ***Colorado***'s doctrine of prior appropriation, as upheld and defined by later case law. [[8]](#footnote-9)8

Methods of scientific data collection, analysis, pre-trial discovery, interactions between opposing experts, and the reliability of testimony in the adversarial setting of ***Colorado***'s water courts improved in the first twenty-five years after the 1969 Act. In my opinion, the use of experts in ***Colorado*** water courts has improved even more in the twenty-five years since. When the ***Colorado*** Supreme Court put forth Rule 11 as part of the 2009 Water Court Rules ("the 2009 Rules"), [[9]](#footnote-10)9interactions between experts took a big step forward. [[10]](#footnote-11)10However, pitfalls remain. These pitfalls result in water court inefficiency and potential **[\*625]**inaccuracy in decision making. At worst, it is conceivable that some water court trial decisions or stipulated decrees, even in recent years, have been entered on the basis of "gamed" disclosures or biased expert testimony.

As we look forward to the next fifty years under the 1969 Act, I propose that it is time to consider further innovations to the Rules, coupled with improved continuing education for testifying experts and greater emphasis on experts' responsibilities to the court. This would lead to better efficiency and accuracy in decision making, ultimately serving the public interest. For the purpose of this paper, I define "efficiency" as optimum utilization of the court's time and applicant's and objectors' resources in litigating an application for a water right. "Accuracy" is defined as court rulings that best reflect objective scientific or engineering evidence presented through unbiased expert testimony.

II. Reliability of Expert Testimony: Not A New Concern

Concerns about the reliability of expert testimony are not new, but clearly are still relevant today. "Far from being new, the putative problem of scientific expert testimony in common law courts has a long and rich history." [[11]](#footnote-12)11As common law and courtroom practice in England and the U.S. developed to a semblance of its present form in the late eighteenth and nineteenth centuries, these concerns included inconsistency of data and results, questionable reliability of the expert's methods, partisanship among testifying experts, incomprehensibility of testimony, and lack of objectivity of expert testimony in an increasingly adversarial setting.

Thus, among the crowds of experts allowed into the nineteenth-century courtroom as expert witnesses, besides the traditional figures of the physician, the cleric, the navigator, the sea captain, and the merchant, we find the growing presence of men of science - chemists, microscopists, geologists, engineers, mechanists, etc. These experts untangled for the court and the jury the complexities of the rising tide of cases involving science. They appraised disputed claims with their experimental techniques, and, in general, offered their knowledge of the basic principles of nature, which the jurors then could apply to the facts at issue before them. In spite of their ascent, men of science quickly found their forays into the courtroom exceedingly frustrating; browbeaten and set against each other by the lawyers, scientific witnesses quickly found that their standard strategies for generating credibility and agreement did not well withstand the adversarial heat of the courtroom. Often, the outcome was an embarrassing public display of eminent scientists zealously opposing each other from the witness stand, a display that casted serious doubt on their personal integrity and on the integrity of their science. [[12]](#footnote-13)12

Collapsing time and again in the courtroom, the scientific ladder often provided the astonished onlooker with a view not of the hard facts of the case, but of definitions in disarray, conflicting hypotheses, inconsistent experimental results, and contradictory conclusions. [[13]](#footnote-14)13

**[\*626]**Judge Learned Hand, in 1901, was even more severe in his opinion of expert testimony:

Having briefly considered the history of the present position of expert witnesses, the really practical question is whether it is the best way to use the information they can give. There are two things I wish to prove: first, that logically the expert is an anomaly; second, that from the legal anomaly serious practical difficulties arise... . There can be, in my opinion, no legal anomaly which does not work evil, because, forming an illogical precedent, it becomes the mother of other anomalies and breeds chaos in theory and finally litigation *.*[[14]](#footnote-15)14

Judge Hand argued that the "anomaly" and resulting "evil" of hearing testimony by persons with special expertise was because a jury is not competent to decide between contradictory views of testifying experts. "Therefore, when any conflict between really contradictory propositions arises, or any reconciliation between seemingly contradictory propositions is necessary, the jury is not a competent tribunal." [[15]](#footnote-16)15The Judge maintained: "One thing is certain, [the jury] will do no better with the so-called testimony of experts than without, except where it is unanimous. If the jury must decide between such they are as badly off as if they had none to help." [[16]](#footnote-17)16

Though opinions of expert testimony have changed over the last century, some underlying misgivings about the use of experts in court remain and should give us pause to reflect on its potential pitfalls.

Moving forward to the last decade of the twentieth century, the *Daubert* decision in the federal courts was reached largely in response to concerns similar, although framed differently, from those expressed by Hand and Golan. [[17]](#footnote-18)17In *Daubert*, following a century of increasing complexity in all of the sciences, the concern was framed as a question about the reliability of scientific expert testimony, particularly in a forensic setting, with increasing specialization and complexity in the scientific and engineering disciplines. For historical context, note that the fifty years since adoption of the 1969 Act are roughly split half pre- *Daubert* and half post- *Daubert*: clearly an important period of time in the ***Colorado*** water courts and for expert testimony.

As shown in the federal courts by  *Daubert*, a trend I have observed generally to be paralleled in ***Colorado***, there has been increasing emphasis on expert witness reliability in questions of admissibility of evidence over the past twenty-five or more years, with the result being an increased gate-keeping responsibility placed on the judges presiding in ***Colorado***'s water courts.

In the ***Colorado*** water courts, increasing emphasis on expert reliability is partly to address questions of admissibility, but is also strongly due to technological advances and more complex tools in hydrology and to more basic data becoming available. Questions of expert reliability in the water courts also are due to increasingly rigorous technical review by objectors as computer models **[\*627]**often become the centerpiece of expert disclosures, continual increase in water demand (thus more competition for water), ever-rising expert fees and costs, and increasing specialization of expertise in the natural sciences.

Post- *Daubert* "best practices" by counsel and experts for the parties in a contested case are not always adhered to in ***Colorado***'s water courts, even today, after the ***Colorado*** Water Court Rules revisions were adopted for cases filed on or after July 1, 2009.

The proponent of expert opinion proceeds at her peril if she fails to Daubert-proof the opinion early on. Today, lawyers must proffer nothing less than their best Daubert-proof expert-witness evidence prior to trial. The challenge is to present the best in a culture where the deep-pocket will gladly force the issue. [[18]](#footnote-19)18

Despite improvements, there are still many issues with experts in ***Colorado***'s water courts. There are still preliminary expert reports proffered that ostensibly adhere to Rule 11 (2009), but, in reality, at best are perfunctory, and at worst they are overt sand-bagging. Happily, such poor products are the exception and not the rule among expert reports. The motivation to proffer marginal scientific and engineering analysis and reporting appears mostly to be economic *.* The applicant's expert initially discloses the minimum technical information, opinions, and decree terms that the applicant and their counsel believe may pass muster. Inadequate or perfunctory preliminary expert disclosures ( *i.e.* "sand-bagging") are proffered by the applicant in the hope that objectors will consider the risk of injury to their own water rights to be minimal, and therefore objectors will stipulate, despite inadequate engineering and insufficient terms and conditions by the applicant, in order to reduce their engineering and legal expenditures. Also, an applicant may hope that one or a few leading objectors will shoulder the burden of paying their own experts to do the analysis correctly and to respond with more complete or protective decree terms and conditions. In these instances, much of the cost burden of expert fees that should be borne by the applicant instead is shifted to the objectors: a form of "gaming the system".

III. Hydrology Reflected in ***Colorado*** Water Law: Keeping Up with Science

The problematic ways courts have viewed the science of groundwater historically is well illustrated by the 1861 Ohio Supreme Court case *Frazier v. Brown*. [[19]](#footnote-20)19The *Brown*Court reasoned:

Because of the existence, origin, movement and course of such waters, and the causes which govern and direct their movements, are so secret, occult and concealed, that an attempt to administer any set of legal rules in respect to **[\*628]**them would be involved in hopeless uncertainty and would be, therefore, practically impossible. [[20]](#footnote-21)20

The *Frazier*court's reasoning reflects the earliest principle of law on groundwater - the so-called English rule, which reflected the science of the time. [[21]](#footnote-22)21At the time *Frazier*was decided, groundwater was considered hidden, secret, and simply not knowable. Geology as a science was only a few decades old, and the science of hydrology (particularly groundwater hydrology) had barely begun.

The Ohio Supreme Court's 1861 decision in *Frazier* can be viewed as consistent with the state of science at the time. Charles Lyell first published *Principles of Geology*, long considered a seminal work in the science of geology, in 1830. [[22]](#footnote-23)22In 1856, the French engineer Henry Philibert Gaspard Darcy published an equation for the flow rate of water in sand filters, "Darcy's Law," in a report on the construction of a new municipal water supply intended to improve the ghastly health conditions in the city of Dijon. [[23]](#footnote-24)23Darcy's Law helped make the "occult" magic of groundwater flows comprehensible and remains a fundamental equation in the water resources community. [[24]](#footnote-25)24Another important French hydraulic engineer, Arsene Jules Emile Juvenal Dupuit, in 1861 - the year of the *Frazier* decision - first quantified the cone of depression of the water table due to pumping a well, using Darcy's Law. [[25]](#footnote-26)25

In the United States, it was not until 1885, twenty-four years after *Frazier*, that T.C. Chamberlin published his paper, *The Requisite and Qualifying Conditions of Artesian Wells*. [[26]](#footnote-27)26Chamberlin's paper was the U.S. Geological Survey's first report on groundwater. [[27]](#footnote-28)27This was the first paper published in the United States to recognize that there are no truly impermeable strata in the subsurface, and that the ultimate source of supply to wells - including confined or artesian wells - is precipitation moving downward through permeable strata. [[28]](#footnote-29)28

If there lingers in the mind any sense of marvel at the flow of artesian wells, it is best to cast it away at the outset. Artesian flow is but an expression of the common law of flowage, made a little unusual, it is true, by its special conditions. Any seeming strangeness springs from our partial observation. " *We see but a part of the stream*." [[29]](#footnote-30)29

However, at the time of Chamberlin's 1885 paper, it had not yet been **[\*629]**worked out how to quantify the amount and timing of groundwater-surface water interactions, and with this, how to codify rights to such groundwater and the analysis of potential injury.

In 1923, Oscar E. Meinzer of the U.S. Geological Survey, building on Chamberlin's work, documented groundwater and surface water interaction in three ways. [[30]](#footnote-31)30First, streams gain water from the zone of saturation where the stream stage is lower than the water table. [[31]](#footnote-32)31Second, streams lose water to the aquifer where the stream stage is higher than the water table. [[32]](#footnote-33)32Third, streams gain water in some reaches and lose water in other reaches, or gain and lose in the same stream reach seasonally or in response to precipitation and runoff events. [[33]](#footnote-34)33

Groundwater-surface water interaction was made quantifiable, in terms of calculating a schedule of time-lagged pumping depletions, by the early 1940s to the 1950s. [[34]](#footnote-35)34In 1940, M. King Hubbert published a landmark paper describing Darcy's Law of groundwater flow in terms of a differential equation conserving mass and energy. [[35]](#footnote-36)35Building upon Hubbert's concept, a 1941 paper by C. V. Theis, [[36]](#footnote-37)36and the often-cited 1954 paper ***co***-authored by Instructor Robert E. Glover of ***Colorado*** A & M (now ***Colorado*** State University), presented mathematical solutions to quantify the amount and lag time of well pumping depletions on a hydrologically connected stream. [[37]](#footnote-38)37

These fundamental scientific advances in hydrology were developed and published in technical literature throughout World War II and the post-war period - a time when groundwater development was increasing rapidly. [[38]](#footnote-39)38The ***Colorado*** Supreme Court found, in 1951, as a presumption, that a claimant of allegedly nontributary groundwater had the burden of proof *"*by clear and convincing evidence *"* that the groundwater diversion does not affect the surface stream. [[39]](#footnote-40)39

Thus, in the post-WWII years, ***Colorado*** statutory and case law stayed current with the science, culminating with the Water Rights Determination and Administration Act of 1969, which was forged out of three competing bills in the ***Colorado*** Statehouse. [[40]](#footnote-41)40The currency to the science with which ***Colorado*** **[\*630]**enacted such far-reaching and prescient public policy in the form of the 1969 Act was remarkable. Later ***Colorado*** statutes and case law refined and extended the concept to embrace optimum use of the available water resource. [[41]](#footnote-42)41Fifty years later, some western states are still struggling, in their water laws and general water rights adjudications, to catch up and fully incorporate the concept of groundwater and surface water as interdependent and to administer water in a robust way as a conjunctive resource.

Notwithstanding the 1951 ***Colorado*** Supreme Court's presumptive "clear and convincing evidence" standard *,*during the post-WWII/pre-1969 Act years, some water rights were decreed with minimal evidence presented by experts or embraced by the courts, at times resulting in a disconcerting silence as to the presumptive groundwater-surface water connection. For example, the Coffin adjudication [[42]](#footnote-43)42decreed, outside of existing water rights priorities, many wells, springs, seeps, drains, and even lakes that originate from sources "that are not part of any waters which are, or would be, tributary to the Cache la Poudre ***River*** or any of its tributaries or any natural streams." [[43]](#footnote-44)43 I am aware of other wells and springs that also were adjudicated as nontributary with evidence that would not meet a "preponderance" standard, much less a "clear and convincing" standard, during the 1950s and 1960s in other ***Colorado*** ***river*** basins.

Part of the lack of attentiveness in addressing the 1951 "clear and convincing evidence" standard in some pre-1969 Act decrees may be because in the late 1940s and early 1950s there were limited detailed aquifer maps of key parameters such as aquifer saturated thickness, aquifer transmissivity, and water table elevations, particularly in areas outside of the major alluvial basins. However, by the mid-1950s, landmark technical and basic-data reports had been published for most of ***Colorado***'s major mainstem-***river*** alluvial basins, including the South Platte ***River*** basin, the Arkansas ***River*** basin, and the San Luis Valley. Thus, lack of data in major groundwater basins does not entirely explain the occasional lack of sound engineering in some water rights decreed between the mid-1950s and enactment of the 1969 Act.

As an example of hydrologic data then available, the first comprehensive published U.S. Geological Survey ("USGS") study on the South Platte ***River*** basin was Water Supply Paper 1378 ("WSP-1378"), which included maps of groundwater levels, a large number of geologic logs of wells, and geologic cross-sections for the lower South Platte ***River*** basin (below Hardin, ***Colorado***, near Greeley). [[44]](#footnote-45)44The WSP-1378 study was published in 1957, using data derived from 189 observation wells, and drilling logs were obtained for 1,767 additional existing wells. [[45]](#footnote-46)45The WSP-1378 study was published at about the same time the ***Colorado*** Division of Water Resources began a concerted effort to develop a **[\*631]**comprehensive database of water well data, concurrent with passage of the ***Colorado*** Groundwater Law of 1957, which required a well permit from the state in order to drill a well. [[46]](#footnote-47)46

Another example of a landmark data-rich study in a major ***Colorado*** alluvial basin was the USGS study by W.J. Powell in the San Luis Valley. [[47]](#footnote-48)47This study, published in 1956, contained numerous aquifer and water table maps and cross sections, with particular detail in the Closed Basin region of the northern San Luis Valley. [[48]](#footnote-49)48

In the Arkansas ***River*** Valley, various ***Colorado*** Water Conservation Board (CWCB) and USGS countywide hydrologic reports were published by the mid-1950s to the late 1960s. There were also earlier, but still valuable, reports published for some major ***river*** basins, for example, Darton's 1906 study of the bedrock aquifers in the Arkansas ***River*** watershed [[49]](#footnote-50)49and Siebenthal's 1910 study of the valley-fill aquifers of the San Luis Valley. [[50]](#footnote-51)50Engineers and hydrologists still rely on basic data from these reports today over 100 years after their publication.

At the time of the 1969 Act, groundwater modeling program codes were not generally available. Most modeling codes were in an experimental state in academia and were intractable to use as compared to much simpler pencil and paper solutions of the Theis and Glover equations. One of the first groundwater models used in ***Colorado*** was a one-layer analog model of the San Luis Valley. [[51]](#footnote-52)51The San Luis Valley analog model was not a computer model. This model consisted of a five-foot wide by ten-foot long pegboard with electrical circuits consisting of 6,400 resistors and 1,600 capacitors, along with transistors and diodes, interconnected to provide electrical analogues to the transmissivity, storage coefficient, and evapotranspiration characteristics of the uppermost (unconfined) aquifer in the Valley, as it was then understood. [[52]](#footnote-53)52Pumping stresses were simulated by imposing electrical currents, and the resulting groundwater levels were approximated by measuring voltages with voltmeter probes placed at various points on the pegboard. If you wanted to change the aquifer transmissivity in a certain area, you had to unsolder and remove the resistors in that area and replace them with resistors of a different resistance value: hardly a nimble and user-friendly model.

Several influential engineering studies on water rights leading up to the 1969 Act endorsed inclusion of groundwater as part of ***Colorado*** water law, clearly recognizing the value of codifying water as a conjunctively used resource. These studies included cooperative engineering analyses on the South Platte ***River*** and **[\*632]**the Arkansas ***River*** by the firms of Wright Water Engineers, Morton W. Bittinger & Associates, W.W. Wheeler & Associates, and Woodward-Clyde & Associates. [[53]](#footnote-54)53Among the conclusory statements in the summary report (1968) by these firms is:

Our studies have confirmed that it is highly desirable to implement planned utilization of our valuable groundwater resources and reservoirs in conjunction with surface water supplies and facilities. Formulation of legislation which will allow and encourage the integrated management, administration and use of surface water and groundwater, without infringement of present vested rights, will require considerable ingenuity on the part of the attorneys and legislators involved. [[54]](#footnote-55)54

Following implementation of the 1969 Act, augmentation plans (e.g., *Kelly Ranch v. Southeastern, Cache LaPoudre Water Users Ass'n v. Glacier View Meadows*) began to incorporate engineering analysis of groundwater-surface water interaction as part of their plans to replace pumping depletions, per the 1969 Act. However, in some of the earlier post-1969 Act augmentation plans, the engineers and the water courts appeared to struggle with, or even to omit, amounts or percentages of consumptive use and return flows. The decrees often did not address time-lagged effects of pumping or return flows.

Early augmentation plans show a learning curve on the part of the water courts. In [*Kelly Ranch v. Southeastern* ***Colorado*** *Water Conservancy Dist., 550 P.2d 297 (****Colo.*** *1976)*](https://advance.lexis.com/api/document?collection=cases&id=urn:contentItem:3RX4-1KB0-003D-93BF-00000-00&context=1516831)*,* the Division 2 Water Court denied the application, reasoning that because no *new* water was being introduced into the Arkansas ***River*** basin system, an augmentation plan had not been proffered. [[55]](#footnote-56)55The court reasoned that the application should have been made for a change in point of diversion, even though the proposed well depletions would be more than offset by drying up certain irrigated fields, and the State Engineer concurred that a sufficient augmentation plan was being proposed. [[56]](#footnote-57)56On appeal, the ***Colorado*** Supreme Court reversed. [[57]](#footnote-58)57

In the closely related case [*Cache LaPoudre Water Users Ass'n v. Glacier View Meadows, 550 P.2d 288 (****Colo.*** *1976)*](https://advance.lexis.com/api/document?collection=cases&id=urn:contentItem:3RX4-1KB0-003D-93BD-00000-00&context=1516831), concurrent with *Kelly Ranch*, the Division 1 Water Court found that an augmentation plan indeed was being applied for, even though no new water was being added to the Poudre ***River*** hydrologic system. [[58]](#footnote-59)58Heard on appeal at the same time as *Kelly Ranc*h, the ***Colorado*** Supreme Court upheld this finding:

The fundamental question in the companion case of [*Cache La Poudre Water Users Ass'n v. Glacier View Meadows, supra*](https://advance.lexis.com/api/document?collection=cases&id=urn:contentItem:3RX4-1KB0-003D-93BD-00000-00&context=1516831), and here, has been whether an acceptable plan for augmentation requires the addition of new water into the **[\*633]**water system, such as the introduction of transmountain diverted water. In Glacier View Meadows one water court ruled that the addition of new water is not necessary, and here another water court has held that it is. We are affirming in Glacier View Meadows and reversing here. Under the circumstances of both cases new water need not be injected to give life and validity to a plan for augmentation *.*[[59]](#footnote-60)59

The *Kelly Ranch*decision and the *Glacier View Meadows*decision clearly endorsed optimum usage of a single, conjunctively used water resource. Notable in these cases is the fact that the court did not include any mention of time-lagging of depletions in either decree.

It was not long before time-lagging of depletions and replacements in plans for augmentation became standard in the engineering proffered by applicants and requested by objectors. By the mid-to late 1970s and early 1980s, before the rise of the personal computer beginning *circa* 1981 and the advent of manageable groundwater model computer codes by the mid-1980s, the most common lagging method was the use of Glover [[60]](#footnote-61)60or similar analysis, including the Stream Depletion Factor (SDF) [[61]](#footnote-62)61method of analysis of lagged well depletions and irrigation return flows. Sets of published maps using SDF contour values, [[62]](#footnote-63)62either based on numerical computer modeling or on Glover analytic solutions, also were used for depletion timing in a number of augmentation plans. Manual or pocket-calculator solutions of Theis (and similar) well-pumping drawdown analysis also were common in this time period in questions of well-to-well drawdown interference.

Fifty years after enactment of the 1969 Act, and over twenty-five years post- *Daubert*, analytic methods such as Glover still are used in professional practice, although such simplified analyses must be used advisedly. It is common for analytic methods to be criticized by experts for objectors if the simplifying assumptions are considered to be violated egregiously. Analytic methods such as Glover have the advantage of being much more economical to perform than any computer model, even though the calculated replacement obligation may be higher than a numerical model would show.

By the early 1980's, personal computers had become common and affordable. By the mid-1980's, there were a number of commonly-available computer codes for numerical groundwater flow modeling (e.g., Prickett-Lonnquist two-dimensional "PLASM" code [[63]](#footnote-64)63and Trescott-Pinder-Larson code [[64]](#footnote-65)64). Modeling **[\*634]**codes such as these eventually led to the easier to use, more flexible U.S. Geological Survey MODFLOW code. [[65]](#footnote-66)65By 1988, MODFLOW had become standardized. Today, water engineers and scientists still use (and occasionally abuse) MODFLOW in updated form.

IV. Science, Human Nature, and Expert Practice in the Water Courts

In water court cases, disagreements among experts arise from factors inherent in science and from factors unrelated to the science. The reasons for disagreement, and potential pitfalls in expert practice, may be better understood by a review of the following factors.

A. Why Do Experts Disagree?

Given that scientists and engineers in an adversarial case have access to the same facts and have generally similar experience and training, why do they so often disagree? The answer, in part, is because science itself is a hypothesis and testing driven empirical process. Science is an adversarial (even if mostly - though not always - collegial) and iterative process that works through hypothesis development, debate, refinement of concepts through data collection, observation, experimentation, analysis, and further technical debate. Any ten geologists directed to analyze a set of well logs and develop from that data a geologic map will come up with ten different maps, although many maps will be seen to have strong similarities. Each map, one should realize, is a graphical hypothesis depicting one expert's interpretation of observed data. Each geologist is likely to hold strong opinions about why her map is better than anyone else's map. However, if the geologists collaborate, or testify in a "hot-tubbing" [[66]](#footnote-67)66situation, it is likely that many of the weaker maps will fall by the wayside even if no single map is endorsed by all. This illustrates the power of open scientific debate and consensus-building.

Beyond the adversarial nature of science, factors that may lead to pitfalls to the unwary in expert witness practice in hydrology are of two basic types: factors that are part of the natural sciences (including computer modeling as a specialized tool of hydrology) and factors that are part of human nature. B. Expert Practice and the Natural Sciences

As with many of the natural sciences, geology - and by extension hydrogeology - is inferential. It is the nature of these sciences to be data sparse. For example, no matter how closely spaced a set of well data for subsurface observations is, we cannot conclude with absolute certainty what is going on between any two wells. We must infer, by exercise of judgment, what occurs between **[\*635]**the data points in terms of continuity of geologic layers and hydrologic characteristics. [[67]](#footnote-68)67Inference, and thus judgement based on training and experience, is always necessary. This leads some to believe that geology is as much art as it is science. [[68]](#footnote-69)68Whether or not this is true, the inferential nature of the natural sciences results in a level of uncertainty in an expert's conclusion. In most instances, the level of uncertainty can be calculated or estimated, although many times the level of uncertainty or systematic error is left unreported.

A related consequence of the inferential nature of the earth sciences, including hydrology, is that as we develop additional data, filling in data gaps over time and distance, and as newer and more sophisticated exploration and analysis tools and techniques become available, geologic and hydrologic interpretations necessarily also change. Thus, it is true to say that "a geological report is simply a progress report." [[69]](#footnote-70)69

The fact that uncertainty is inherent in data and analyses as part of expert disclosures and testimony consulting practice results in a conflict between science and how law usually is codified in an either/or sense. That is, is there injury under the law, or is there not? Does the physical situation meet a certain legal criterion or threshold, or does it not?

To a novice in the law, the problems of groundwater rights seem to straddle awkwardly the physical and social realms. The law - a formal set of rules by which society is ordered - seems to the physical scientist a strangely confusing and confused tool with which to define, even in a social context, parameters and limits of a physical continuum. [[70]](#footnote-71)70

With the proliferation of computer models used predictively to answer injury-related questions in water disputes, it is necessary to review the nature of modeling and models (conceptual models and mathematical or computer models) from a hydrologist's perspective.

A "model," in hydrology, is a mathematical construct that purports to simulate a real-world hydrologic system. No matter how complex we make it, a model is necessarily simplified as compared to a real-world system.

An analytical model, such as Glover stream depletion, assumes and describes a closed system, usually highly simplified from nature. A closed system, as it is considered in science, is a part of the world for which one makes sufficient simplifying assumptions so she knows (or is simulating to know) all relevant components, such as inflows and outflows to and from that system, as well **[\*636]**as the exact physical nature of that system (e.g., aquifer thickness and transmissivity). A thermos bottle might define a closed system if one assumes that the vacuum is perfect so that no heat enters or leaves the bottle. Although we know this is not strictly correct, this simplifying assumption might be just fine for the particular problem one is trying to solve, and it may make a complex, intractable problem readily solvable. The Glover equation, with many simplifying assumptions, provides a "closed-system" solution to the time lag of stream depletions due to well pumping. [[71]](#footnote-72)71

A computerized numerical model, by contrast, simulates an open system, and can vary from simple to extremely complex depending on the problem at hand.

The fact that a numerical (open system) or analytical (closed system) model is always, necessarily, based on a simplified conceptual model of the real-world hydrologic system leads to an important realization: even if there is scientific consensus that the model appropriately represents the real-world system, and the model represents observed data accurately, is the conceptual model - the set of ideas upon which a computer model is based - necessarily reliable? The answer is no; but it is true, nonetheless, that the adversarial process of science - hypothesis testing and debate - is more likely to result in a reliable model than a single modeler working in a vacuum.

A hydrogeologic conceptual model of a stream-connected aquifer, or other groundwater region of interest, is a set of narratives, data, or graphics (often all three) that summarize a best estimate of the hydrogeologic layering, boundaries, physical characteristics, and inflows and outflows that describe the system under study. One expert's conceptual model of an aquifer system is unlikely to be the same as another expert's conceptual model.

Many thoughtful people consider conceptualization one of the thorniest problems in modeling (if not science). Every model has as its foundation a conceptual model. The conceptual model is the basic idea, or construct, of how the system or process operates; it forms the basic idea for the model (or theory). [[72]](#footnote-73)72

Given that there are likely to be fundamental differences in conceptual models, even before any analytic or computer model is developed, how do we best proceed as experts when a model is needed in a water case, but in the adversarial setting of water court, there are seemingly unresolvable disagreements among experts?

The conceptual model dilemma suggests that the best use of science in water cases will result from the water court process emulating, to the extent possible, the adversarial yet open-debate atmosphere of groundwater hydrology. That is, if we are to use the best that science and engineering have to offer the courts, we should not seek to quell the adversarial nature of the process, but instead we should use the nature of the peer review/debate scientific process to the court's advantage. We may work toward this goal by encouraging or mandating greater collaboration among stakeholders and their experts, so that competing conceptual models can be vetted and the best conceptual model selected **[\*637]**by collaborative discussion and debate to help find common ground and to highlight valid scientific disagreements for the issues at hand.

Although science does not proceed smoothly and incrementally, it is one of the few areas of human endeavor that is genuinely progressive... . Science is, above all, an adversarial process. It is an arena in which ideas do battle, with observation and data the tools of combat. The scientific debate is very different from what happens in a court of law, but just as in the law, it is crucial that every idea receive the most vigorous possible advocacy, just in case it might be right. [[73]](#footnote-74)73

In my experience, the open debate/collaborative discussion approach has worked in large cases in which competing numerical models, or where particular parts, inputs, or uses of a model, are at issue. Open debate and incremental consensus-building among experts, with relevant non-technical input from stakeholders, has been the general - and, in my opinion, successful - framework of at least one recent basin-wide rulemaking proceeding (Division No. 3 Groundwater Withdrawal Rules). [[74]](#footnote-75)74However, in most contested cases of small to moderate size, such an open and lengthy peer-review process would need to be downscaled and made timely to be efficient within the constraints of the Rules, the court docket, and client/stakeholder budgets and schedule.

Important characteristics of data-founded and inference-based natural sciences, including hydrology, are the accuracy, precision, and reliability of the data and of analysis results on which expert opinions are based. How do we judge whether the results of a scientific or engineering analysis are useful and reliable? Assuming scientists and engineers have been assiduous in developing estimates of the accuracy and precision of their data and analyses, how do we, as testifying experts, make sure our evidence is admissible, and how do we effectively communicate the reliability of our findings to the court?

The federal courts use one standard of admissibility that is based on reliability. "Additionally, in the case of a particular scientific technique, the court ordinarily should consider the *known or potential rate of error* ... and the existence and maintenance of standards controlling the technique's operation. [[75]](#footnote-76)75

In ***Colorado***, [*C.R.E. 702*](https://advance.lexis.com/api/document?collection=statutes-legislation&id=urn:contentItem:63CY-K2F1-DYDC-J09P-00000-00&context=1516831) is the standard for admissibility of expert testimony:

If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise. [[76]](#footnote-77)76

**[\*638]**In [*People v. Shreck, 22 P.3d 68 (****Colo.*** *2001)*](https://advance.lexis.com/api/document?collection=cases&id=urn:contentItem:42WP-2K90-0039-4093-00000-00&context=1516831), the ***Colorado*** Supreme Court adopted [*C.R.E. 702*](https://advance.lexis.com/api/document?collection=statutes-legislation&id=urn:contentItem:63CY-K2F1-DYDC-J09P-00000-00&context=1516831) as the appropriate standard for determining the admissibility of scientific evidence. [[77]](#footnote-78)77The Supreme Court decided that three criteria should determine the reliability and relevance of the evidence: (1) the reliability of the science; (2) the qualifications of the witness; and (3) the usefulness of the testimony to the trier of fact. [[78]](#footnote-79)78

The ***Colorado*** Water Court Rule 11(b)(5)(E), with respect to expert disclosures, states, "the expert shall not include anything in his or her expert report, disclosure, or opinion that has been suggested by any other person, including the attorney for the expert's client, *without forming his or her own independent judgment about the correctness, accuracy, and validity* of the suggested matter." [[79]](#footnote-80)79Rule 11 details pre-trial procedures, directs how cases before the water court are managed, details disclosure procedures, and directs how case issues may be simplified. As such, Rule 11 directs how, when, and under what circumstances experts will interact with each other, such as by expert disclosures and expert meetings.

Rule 702 does not have a requirement that the expert's "independent judgement about the correctness, accuracy, and validity" must be included in her expert disclosure, only that any suggestion by others for the expert to express an opinion on a certain topic must be independently judged by the expert herself. In my experience, few expert disclosures submitted in the water courts, either before or since the 2009 Rules changes, have included a specific opinion addressing the accuracy or validity of a particular analysis, although broad statements as to reliability of the analyses performed are common.

There have been several large model-focused cases in the ***Colorado*** water courts in the post- *Daubert* and post- *Shreck* years in which conflicting and largely unresolved differences in expert opinions on model accuracy or validity were crucial to the courts' rulings (e.g., [*Bd. of Cty Comm'rs v. Sportsmen's Ranch, 271 P.3d 562 (****Colo.*** *App. 2011)*](https://advance.lexis.com/api/document?collection=cases&id=urn:contentItem:83H5-9Y81-652G-F03F-00000-00&context=1516831) [[80]](#footnote-81)80and  *San Luis Valley Confined Aquifer New Use Rules for Division 3*, No. 2004 CW 24 (***Colo.*** Water Division No.3 2004) [[81]](#footnote-82)81). The conflicting expert opinions, in turn, highlighted conceptual models, sensitivity analyses (or lack thereof), and calibration statistics to attack or to defend the reliability and validity of model results. These aspects were primary foci of testimony in these cases.

Most water cases are much smaller in scope. Many cases do not include calibrated groundwater models, and most cases do not include the level of detail in analysis or testimony that were relied on in *Sportsmen's Ranch* or the *San Luis Valley Confined Aquifer New Use Rules* cases. Smaller cases, in my experience, limit or omit discussion entirely on accuracy and reliability of data, **[\*639]**analyses, and results.

In my opinion, the testifying experts in the community of water professionals in ***Colorado*** have done a generally poor job of communicating to the water courts, through expert disclosures and testimony, the estimated accuracy or precision of data or analyses upon which expert opinions were based and thereby have been mostly silent as to the reliability of analysis results. Such estimates may or may not be elicited in cross-examination, which many times leaves the courts to make their own judgments as to reliability.

Engineers and scientists train in the concepts of accuracy and precision based on measurements and estimates of parameters of the physical world. However, in expert disclosures and court exhibits, many practitioners report extremely small values, or values with too many decimal places, that are far smaller than are justified by the accuracy of the parameter estimates. It is common to see tabulations of augmentation replacements carried out to the fourth or fifth decimal place where there is no physical basis for reporting beyond one or two decimal places based on what we know about such parameters as aquifer thickness and transmissivity. In my experience, even the best single-well aquifer test, with well-controlled variables and multiple observation points, seldom can be relied on to give aquifer transmissivity better than plus or minus 5% accuracy, or aquifer storage coefficient values better than plus or minus 20% accuracy. Despite this, I have often experienced pushback from other engineers when I have suggested limiting the decimal places reported to reflect the limitations of the empirical data or the methods of analysis used.

There is also a difference between how many decimal points an expert can calculate and what can be administered or reliably projected out in time. For example, stream depletions from a Glover analysis or a model can be calculated out to as many decimals as the computer processor will allow, but few of those decimal places are significant; that is, few decimal places actually carry meaning and thus are reliable. This is relevant, for example, in augmentation or replacement plans in "wrapping the tail" of unit response functions (URFs) to reasonably limit the tens or hundreds of years the computations indicate. It is also relevant in regard to the reliability with which an aquifer test,for example, can determine what the aquifer properties are at a particular location.

In the past, attorneys were often unsupportive of experts reporting analyses of accuracy or reliability, even to the point of requesting that experts refrain from any discussion of uncertainty or rates of error in expert disclosures. Attorneys were often reluctant for the expert to admit that "errors" existed in his data or analysis. Fortunately, in recent years, this situation has changed for the better. In science and statistics, "errors" are not considered mistakes or blunders: they are levels of estimated or calculated uncertainty inherent in the data or the method of analysis.

If experts omit any discussion of the limitations of the empirical values used or the analyses performed, as is often the case, it may give a false impression to the water court of what is meaningful or predictable and therefore what is reliable. Such an omission appears to contravene the intent of [*C.R.E. 702*](https://advance.lexis.com/api/document?collection=statutes-legislation&id=urn:contentItem:63CY-K2F1-DYDC-J09P-00000-00&context=1516831), according to Witwer and Jones who point out that the purpose of expert testimony is to " assist the trier of fact [to] ... understand the evidence or ... determine a fact in issue" and "... that an expert's primary duty is to the court, not to the **[\*640]**litigants." [[82]](#footnote-83)82

Unfortunately, omission of any discussion of scientific error or uncertainty remains common in expert disclosures, and at this time, there is no explicit disclosure requirement in the Rules regarding accuracy or precision in engineering and scientific analyses.

C. Expert Practice and Human Nature

The literature on water management and governance, and on human cognition, provides evidence that there are a number of factors inherent in human nature that may create pitfalls to testifying experts:

Groundwater professionals have a strong personal affinity and identity to their work given that imagination and creativity are key parts of developing their working hypotheses. The ownership of the creativity associated with imagining what is going on in the subsurface can lead to a dueling experts situation. Conflicting conceptual hydrogeologic models are also part of the formal training of hydrogeologists focusing on the intellectual method of multiple working hypotheses introduced in the late 1890s by the first hydrogeologist in the US, Thomas Chamberlain. The structure of the method of multiple working hypotheses revolves around the development of several hypotheses to explain the phenomena under study. [[83]](#footnote-84)83

"Scientific conflicts arise over specific material related to the management of the resource in question, scientific methods employed by researchers, and broken relationships between scientists and the stakeholders they report to." [[84]](#footnote-85)84

A lack of expert consensus in groundwater hydrology may be due to epistemic differences between interested parties, resulting in "embedding" a particular party's viewpoint or "politics" into a groundwater flow model as it is conceptualized, calibrated, and used:

Groundwater models are more than simulations of subsurface dynamics. Rather than viewing groundwater models as simplified pictures of nature with which to make policy decisions, we are better off understanding them as "world builders" - as tools that embed, enact, and circumscribe subsurface politics as they produce subsurface knowledge and shape socio-ecological outcomes. [[85]](#footnote-86)85

If the "epistemic" argument is true, it suggests an absence of expert collaboration and debate, particularly in the early stages of developing a rational conceptual model into a computer model. Such early debate may help avoid "embedding" one particular party's viewpoint. Masid states this concern in simpler terms:

**[\*641]**

The first stage in constructing a model is defining its purpose. If that purpose is to support the case of the party that retained the expert, then the model will be inherently biased. If that purpose instead is to inform the court or tribunal then adversarial bias and partisanship will be minimized. [[86]](#footnote-87)86

Realistically, it is difficult to imagine an expert openly declaring that the purpose of his model is to support his client's position. However, these sources illustrate that bias, whether due to unbending "ownership" of one's conceptual model or due to partisanship favoring one's client, is a strong and deep-seated force in human nature and in expert practice. In my experience in the water courts and similar adversarial venues, the most common human-nature pitfall is advocacy among experts and the bias that can result in expert testimony. "The attorney is an advocate; it is his job to take a side and argue it with passion and conviction (within the parameters of factual reality and legal precedent). It is not the expert's job to be an advocate for the client, only for the objective truth." [[87]](#footnote-88)87

Contrast this with the reality that "although embedded in the scientific culture of consensus, the testifying expert is uncomfortably aware that he or she is expected to act as an advocate and that both the party for whom he or she is testifying and the party's lawyer expect the expert to testify in a partisan way." [[88]](#footnote-89)88

The client for whom the expert is testifying obviously has his own partisan point of view that favors his position, which is, broadly, to minimize the client's cost and risk and (if the client is the applicant) to maximize reward. Counsel has a time-honored role to advocate for his client's position. As an advocate, an attorney may, with impunity, omit facts or situations that do not help the client's cause. The attorney likely will take the position that if opposing counsel does not raise an issue, it will be left unsaid. [[89]](#footnote-90)89Neither client nor counsel typically is under oath, and each is motivated to advocate a particular view of the facts. [[90]](#footnote-91)90For testifying experts under oath, there is a fine line between acceptable, ethical professional loyalty to one's client and advocacy possibly resulting from adversarial bias: "engineers, in the fulfillment of their professional duties, shall... act for each employer or client as faithful agents or trustees." [[91]](#footnote-92)91

I believe that the line between an expert's acceptable professional loyalty and unacceptable advocacy is blurry, and experts cross this line too often. Bias is inherent in human cognition, and it therefore can influence expert analysis and testimony, either consciously or unconsciously.

**[\*642]**What is cognitive bias? There are many forms of nonobjective thinking inherent in how humans process information, all of which may fall under the general umbrella of "cognitive bias". Simply put, "[a] cognitive bias is a systematic error in thinking that affects the decisions and judgments that people make." [[92]](#footnote-93)92Confirmation bias is a type of cognitive bias that hampers objective analysis: "Confirmation bias, as the term is typically used in the psychological literature, connotes the seeking or interpreting of evidence in ways that are partial to existing beliefs, expectations, or a hypothesis in hand." [[93]](#footnote-94)93

Clinical experimentation shows that humans are subject to confabulation, a form of unconscious confirmation bias, even when we are under no pressure of loyalty to a conceptual model or to a party's position:

When we confabulate ... we tell a story that is fictional, while believing that it is a true story. As we are not aware that our story is fictional, this is very different from a lie: we have no intention to deceive. So in confabulation there is a mismatch between what we aim to do (tell a true story) and what we end up doing (tell a fictional story). We tend to confabulate when we are asked to explain our choices because we don't always know the factors responsible for our choices. Yet, when asked why we made a choice, we offer an explanation. The explanation can sound plausible, but is not grounded in the relevant evidence because it doesn't take into account some of the factors determining our choices. [[94]](#footnote-95)94

In a classic experiment, psychologists at the University of Michigan displayed several common items, such as socks, to survey participants and asked them to select an item. Participants consistently preferred the items on their right-hand side. When asked to explain their choices, they did not mention the position of the items. Instead, the participants attributed their choices to the superior texture or the color of the chosen item, even when all items were identical. This is confabulation. Unconscious of some factors affecting their choices, the participants did not base their explanations on relevant evidence, but instead gave plausible but false reasons for their choices. This experiment shows that we as humans do not always realize or admit that we do not base our choices solely on objective analysis of relevant evidence. [[95]](#footnote-96)95

Are experienced professionals engaged in the practice of science or engineering, particularly those who provide expert testimony, aware of this pitfall and thus mostly immune from confabulation or confirmation bias? In my experience, many testifying experts are unaware of this pitfall. Note that confabulation or confirmation bias, as the University of Michigan study describes, may occur without any influence by the expectation of loyalty or partisanship to the client's position. These influences generally affect testifying experts. Clients (and, often, counsel) expect that the expert will act in a manner evincing loyalty **[\*643]**to the client's cause. Thus, there seems to be a high potential for unconscious, unrecognized bias among testifying experts.

A more descriptive term for confirmation bias that directly addresses this concern in regard to expert testimony is adversarial bias. Masid defines adversarial bias in her "Dividing the Waters" survey and dissertation:

My proposal was to use the term "adversarial bias" and define it as "predisposition, inclination, or favoritism towards the party who called or hired the expert." I also discussed the proposed change with several first phase pilot-testers. There was concurrence [by the thesis committee and outside reviewers including practicing judges and attorneys] that this was an appropriate definition and approach. [[96]](#footnote-97)96

It is important to note that adversarial bias does not address or distinguish whether the expert's bias is conscious or unconscious.

Academic literature on the use and admissibility of forensic evidence in court contains extensive documentation on adversarial bias in expert testimony. [[97]](#footnote-98)97I have observed what I believe to be adversarial bias by testifying experts in a number of water court trials and ***Colorado*** Division of Water Resources administrative hearings. Generally, in my experience, bias is probably not deliberate or conscious. However, there have been a few egregious instances where I suspect that deliberate "fudging" or "slanting" occurred in data selection, analysis, model development, formation of opinions, and testimony.

If it is true that most experts commit adversarial bias unconsciously - the expert honestly feels that he is analyzing, reporting, and testifying in an objective and non-partisan manner - it is probably more difficult to identify and prevent than if committed deliberately. This is due to the subtlety and elusiveness of unconscious confabulation or bias.

Whether committed unconsciously or consciously, there is strong evidence that adversarial bias among experts does exist. Clearly, adversarial bias, whether conscious or unconscious, is detrimental to the accuracy and efficiency of the water court process. To combat it, experts must learn to realize that adversarial bias can and does occur. I suspect that many, if not most, experts will deny that they ever were subject to adversarial bias. However, the literature and research strongly suggest otherwise. [[98]](#footnote-99)98

The Dividing the Waters survey [[99]](#footnote-100)99shows that judges encounter adversarial bias among testifying experts in ***Colorado*** and neighboring states. Of the responding judges to the question "Have you encountered adversarial bias on the part of the expert [predisposition, inclination, or favoritism towards the party **[\*644]**who called or hired the expert]?", over 59% of the respondents had encountered adversarial bias often or always. Over 34% encountered adversarial bias occasionally, and only 6% never encountered adversarial bias. [[100]](#footnote-101)100Masid also noted that, "The types and frequency of expert testimony varied, however geology and hydrology were seen most often." [[101]](#footnote-102)101

The findings from the 2007 Dividing the Waters Survey should give pause for self-reflection to practicing water engineers and scientists who testify as experts in the water courts and administrative venues. Clearly, the Water Court Committee took the results of the Dividing the Waters survey very seriously, as evidenced by the 2009 Rules changes two years after the survey. With ten years of case experience after the 2009 Rules changes, in my view, the situation has improved. However, in my experience, adversarial bias among experts still occurs with disconcerting regularity in the water courts and administrative venues in ***Colorado***.

Adversarial bias by testifying experts cannot help but damage the accuracy of court decisions not only in the case at hand, but also in future cases. For example, if the court accepts a biased technical concept or result as factual, then the bias may lead to an inaccurate ruling in the future.

V. The Care and Feeding of an Expert Witness

Given the apparently high probability that adversarial bias can and does occur among experts testifying in the water courts, along with the possible occurrence of other types of extrinsic (science) or intrinsic (human nature) pitfalls to the objectivity of the testifying expert, how have engineers and scientists' training, experience, and continuing education (CE) prepared them? The answer is not very well, and not very consistently.

Typical undergraduate and graduate scientific and engineering curricula do not address professional ethics of consulting practice, much less the ethics of testifying as an expert witness. If engineers and scientists receive training, they often undertake the training through continuing education courses, webinars, short courses, and workshops. For example, the American Society of Civil Engineers ("ASCE"), [[102]](#footnote-103)102American Water Resources Association, [[103]](#footnote-104)103American Council Engineering Companies, [[104]](#footnote-105)104and other professional organizations offer courses on the subject. Some engineers and scientists who regularly appear as expert witnesses in ***Colorado***'s water courts are aware and take advantage of the workshop offerings by the ***Colorado*** Bar Association CLE. [[105]](#footnote-106)105

Requirements for professional registration or certification, as encouragement to CE on these issues, is inconsistent. In ***Colorado***, the CE picture is not **[\*645]**rosy. Presently, there is no CE requirement for Registered Professional Engineers ("PEs") in ***Colorado***. [[106]](#footnote-107)106The most current review of CE for PEs in ***Colorado*** was by the certifying agency, the Department of Regulatory Agencies (DORA), in 2013. This review was done following an application to DORA for mandatory CE for renewing PEs by the ***Colorado*** Section of ASCE. Among ***Colorado*** ASCE's reasons for the request was: "The occupation of engineering is continually making advances in knowledge through research and application... . Engineers must be well aware of changes in their profession regarding the knowledge base." [[107]](#footnote-108)107

After review, DORA recommended against mandatory CE for renewing PEs to the ***Colorado*** General Assembly:

With respect to the application submitted by the ***Colorado*** Section of the American Society of Civil Engineers (Applicant), an affirmative conclusion is not warranted based upon the information provided in the application, and DORA's review and analysis of that information. The Applicant did not establish that the public consuming the services in question would likely be protected through the imposition of mandatory continuing education. [[108]](#footnote-109)108

All of the fifty states, plus the District of Columbia and Puerto Rico, require registration for engineers in professional practice within their jurisdictions. Of these, forty-one states require CE professional development hours (PDH) for PE renewal. Only nine states (including ***Colorado***) and the District of Columbia presently do not. [[109]](#footnote-110)109CE requirements for PEs vary widely. Most states require between eight and twenty-four CE professional contact hours per year, but the requirements vary by state as to hours and content. Some require ethics CE hours, although most do not. The majority of states do not require pre-approval of CE hours or classes, although many states do random post-audits. [[110]](#footnote-111)110

No Professional Geologist certification is offered, or is required, by the State of ***Colorado***, although ***Colorado*** does have a statutory definition of professional geologist:

"Professional geologist **"** is a person who is a graduate of an institution of higher education which is accredited by a regional or national accrediting agency, with a minimum of thirty semester (forty-five quarter) hours of undergraduate or graduate work in a field of geology and whose post baccalaureate training has been in the field of geology with a specific record of an additional five years of geological experience to include no more than two years of graduate work. [[111]](#footnote-112)111

Many practicing geologists, including hydrogeologists, in ***Colorado*** and in **[\*646]**other states seek and maintain certification from the American Institute of Professional Geologists (AIPG), or hold a geologist certification from one or more states (e.g., Wyoming, Texas, California), or both. AIPG offers and encourages CE, but presently has no CE requirements to renew or maintain certification.

According to the National Association of the State Boards of Geology (ASBOG), thirty-one states and Puerto Rico currently require practicing geologists to be certified, and of these, only twelve presently require CE professional development hours. CE PDH hours for certified geologists vary from twelve to thirty annually. It is not clear from the ASBOG information which states require professional ethics credits as part of CE requirements. [[112]](#footnote-113)112

Many water professionals and hydrologists in ***Colorado*** and elsewhere, in my experience, take it upon themselves to participate in CE as a matter of personal pride and professional growth. However, except for out-of-state licensure or certification where annual or biannual CE PDH are required, CE for engineers and geologists in ***Colorado*** is entirely self-directed and thus can be hit-or-miss in terms of the number of PDH per year and CE content. Ethics training as part of CE, and in particular the testifying expert's responsibility to the court, is not typically required or mentioned even in states that require CE PDH to maintain registration or certification. No states, so far as I have found, require expert witness or professional ethics CE credits for engineering or scientific experts specifically engaged in expert witness work.

In my experience, the majority of expert witnesses practicing in ***Colorado***'s water courts have not been formally educated or trained in developing expert disclosure reports or giving expert testimony, or in the pitfalls that await the unwary. Training, such as it is, typically is gained on the job. Many of us, at least the older generation of testifying experts, received instruction of a sort from partisan "woodshedding" by counsel as part of the school of hard knocks of witness preparation for contested trials.

James Fenimore Cooper originated the phrase "horse-shedding the witness," referring to attorneys who lingered in carriage sheds near the old courthouse in White Plains, New York, to rehearse their witnesses. [[113]](#footnote-114)113"The term "horse-shedding,' or "wood-shedding,' describes conduct that may come close to ethical boundaries, while the term "witness preparation" is generally understood to be a professional obligation." [[114]](#footnote-115)114

In the past fifteen-plus years, accelerating after adoption of the 2009 Rules innovations, some technical experts (although in my opinion too few) have taken advantage of workshops and symposia on expert practice. After the water court Committee of the ***Colorado*** Supreme Court voiced its support following the Dividing the Waters survey, the ***Colorado*** Bar Association (CBA) CLE has become perhaps the best current outlet for expert education in water court practice in ***Colorado***:

**[\*647]**

In addition to the rule changes, the committee recommended the creation of an ongoing educational program designed specifically for experts, attorneys, referees, judges, and state water administration officials involved in water court proceedings. This voluntary program will give water professionals the opportunity to refine their knowledge in the technical areas of hydrology and related fields, presentation of expert testimony, and other subjects especially relevant to water court practice. [[115]](#footnote-116)115

Judges are well aware of the advocacy role of the attorneys who practice in front of them. According to the results of the Dividing the Waters survey, judges also anticipate that testifying experts tend to advocate for their clients' positions and, further, to show adversarial bias: "According to the [Dividing the Waters] survey results, water judges and administrative hearing officers, "adversarial bias' is the most serious problem they have encountered with expert witness testimony." [[116]](#footnote-117)116

Of the judges and administrative hearing officers in ***Colorado*** and surrounding states who responded to the Dividing the Waters survey, 59% of the respondents reported encountering adversarial bias frequently in an expert's testimony. [[117]](#footnote-118)117This provides insight into the seriousness of the problem and the depth of judges' concerns about advocacy and bias in expert testimony in the courtroom. These results should provide a strong incentive for consistent CE, including training and refreshers in professional ethics and potential pitfalls that await the unwary testifying expert.

VI. Looking Ahead: Improving Expert Practice in ***Colorado***'s Water Courts

If we accept the premise that adversarial bias and partisan pressure among experts does occur, how should expert training, CE, and future rule changes be crafted to improve objectivity, accuracy, and efficiency, while reducing bias? In short, given relations between clients, counsel, and experts in an adversarial setting, how should any further changes to the Rules and CE for experts be crafted?

As with most court settings, ***Colorado***'s water courts are adversarial venues, and I do not see that that will change, nor should it change. The adversarial nature of review from different viewpoints allows the science from those multiple points of view to be heard by the court. The adversarial process ensures that even a minority technical viewpoint, if scientifically defensible and supported by evidence, has a chance to prevail. The court, of course, has not only the decisionmaker's role in weighing the evidence from the different points of view presented, but also the gatekeeper's role in deciding on the admissibility of evidence. I see no reason to attack this system. It has served the public interest well and continues to do so.

With no end in sight to increasing specialization and complexity in the hydrologic sciences, judges face the specter of having to become scientific experts in hydrology in order to sift the evidence and arrive at accurate decisions in **[\*648]**complex water cases. In my view, this need not happen. The situation underscores the need for careful, assiduous preparation of expert reports and clear expert testimony so that the judge is not burdened with becoming an expert in arcane subspecialties within hydrology in addition to their other roles as gatekeeper and trier of fact.

Given the potential pitfalls and the adversarial nature of science and the water court process, including partisan pressure on testifying experts, changes to the Water Court Rules and to scientist and engineer CE should be crafted to give the testifying expert stronger intellectual tools needed to remain objective under the pressure of partisan expectations of client and counsel, and to understand the potential pitfalls to expert witness objectivity. Realization of pitfalls and how experts can become cognizant of them - and thereby help neutralize their own potential bias - needs to come from training/CE and also from applied heat via rule innovations and emphasis on the experts' responsibilities to the courts.

Any new CE requirements and rule changes should be accomplished while preserving the essential nature of the adversarial process. This is so that the best aspects of the open debate process in science, including opportunities for collaboration among experts to the extent possible, are available to aid the courts in enhancing the accuracy and efficiency of decision-making.

Review and input to the court by a disinterested technical expert retained by all parties but reporting directly to the court, including the Water Referee, is allowed under the present rules. [[118]](#footnote-119)118Use of a single expert has a number of advantages in addressing and minimizing expert witness pitfalls, although in my experience, this option is seldom exercised. Each party, unsurprisingly, wishes to "hold its cards close" as long as possible, considering their chosen expert to be a potential hole card in the poker game of water court. It may be necessary, in certain cases, for the court to mandate use of a single expert to be retained by the parties, or for the court to retain its own disinterested "third party" expert at the expense of the parties. Use of a single expert to advise the court is not a new concept. Learned Hand recognized long ago that, "It is obvious that my path has led to a board of experts or a single expert, not called by either side, who shall advise the jury of the general propositions applicable to the case which lie within his province." [[119]](#footnote-120)119

If the disinterested expert is retained in addition to the parties' own experts and not as the sole expert in the case, it would be advantageous for her to provide input to the Water Referee at several points in the process.

The expert can assess and opine to the Referee on the adequacy of the initial science and engineering proffered by the applicant's expert. The third-party expert, through the court, would be able to advise the Referee (presumably within the Referee's authority under Rule 6(b) "Adequacy of the Application") to reject initial engineering reports and direct that a more complete and sufficiently understandable (by a layman) disclosure be prepared before it is accepted by the court. The expert could also advise the Referee to dismiss the **[\*649]**application as incomplete or by failure to comply with the Rules under the authority of Rule 6(p).

The third-party expert can also assess and opine to the Referee on the adequacy of the experts' joint statement of disputed issues. It may also be advantageous to have the third-party expert attend the expert meetings of the parties' experts. This would help obviate *pro-forma* expert meetings and joint statements that do too little to find common technical ground and move parties away from entrenched positions.

If the court directs the parties to mediation, the court's disinterested expert should be able to participate as an advisor to the mediator. Preparatory to mediation, the court's expert could educate the mediator on the relevant technical issues of the case.

Third-party expert review and advisement to the Water Referee is envisioned as being similar in scope to, and deriving its authority from, the Water Court Rule 3 requirement for ensuring completeness of applications submitted to the water court and also the amended Rule 6 requirement for thorough review by the Water Referee before any case is re-referred. [[120]](#footnote-121)120

Other potential innovations to the Water Court Rules to improve expert testimony and reduce the potential for adversarial bias, and thereby improve efficiency and accuracy of court decisions, are noted in recent literature, including the 2007 Dividing the Waters survey. [[121]](#footnote-122)121

I support increasing the emphasis by the water court to testifying experts that they are directly responsible to the court. The Expert Declaration, currently required under the Rules, addresses this already. In my experience, testifying experts typically understand this responsibility and take it seriously. However, its importance is often lost in the hurly-burly of trial preparation and the strong partisan influence of counsel and clients on testifying experts. Once a case is re-referred, I recommend requiring a brief telephonic meeting of the parties' experts with the Water Judge or the Water Referee along with the court's expert to emphasize the experts' responsibilities to the court. Through this meeting, it can be reinforced to the experts that their duty is to the court, that they are not advocates for the parties that hired them, that they are under oath to tell the whole truth, and also to warn the experts against acting in a biased or nonobjective manner.

Experts found not to be adhering strictly to the rules, by producing inadequate or "sand-bagging" initial engineering reports, for example,, or foot-dragging in expert meetings or other settlement negotiations, should be subject to suspension against testifying in the subject case before the water court. If the violation is egregious or repeated, the expert would be held in contempt. [[122]](#footnote-123)122

Other actions that should be considered within the present authority of the court (including the Water Referee), or for innovations to the rules, include the following.

**[\*650]**There should be an increased emphasis on expert collaboration and to consider opportunities for early mediation throughout the water court process.

If a case is directed to mediation,the experts for all parties should be required to be present in the same room, at least at some times, during the mediation. This would encourage open discussion on issues and help minimize partisan influence on the experts due to the presence of clients and attorneys in the room. Ping-pong ball mediation, where the mediator bounces back and forth from room to room, each room occupied by an adverse party, does nothing to promote communication and open debate among experts, and in my experience, can result in entrenchment of client's or expert's positions. I understand the need mediators feel (at least in some cases) to keep the parties separate. Feelings run high, and acrimony can bubble up easily. However, at appropriate times, the mediator should "hot-tub" the experts in a separate room apart from clients and counsel to sort through the technical issues and try to identify points on which to agree.

The rules presently have no requirement that the expert's "independent judgement about the correctness, accuracy, and validity" must be included in her expert disclosure, only that any suggestion by others for the expert to express an opinion on a certain topic must be independently judged by the expert herself. Expert disclosures should include a statement of the estimated or calculated error or uncertainty in any data or analysis, or an explanation of why such an estimate or calculation is not possible to provide. This would help overcome misapprehension by the court of the accuracy of reported values - for example, reporting lagged pumping depletion timing to four or five decimal places where it is doubtful that more than one or two decimal places are actually meaningful and thus reliable.

In trial, the water court should be allowed to direct the experts to testify in a "hot-tubbing" manner, where the expert witnesses are called to sit together as a panel (the hot tub). [[123]](#footnote-124)123While in the hot tub, each expert summarizes what they see as the major issues. The experts can comment on the other experts' presentations and (at the court's discretion) may ask questions of the other experts. Counsel and the court would ask questions and elicit rebuttal sequentially among the experts. [[124]](#footnote-125)124"Hot-tubbing" testimony, prior to traditional direct and cross examination of the experts, was considered in the Dividing the Waters survey, and it received favorable responses of the judiciary respondents (from ***Colorado*** and adjoining states): favorable (definitely or probably yes) by 30.9%; unfavorable (definitely or probably no) by 45.5%; and undecided 23.6%. [[125]](#footnote-126)125Ten years after the 2009 Rules innovations, it may be timely to resurvey the ***Colorado*** judiciary and ask the same or similar questions.

In certain multi-party cases such as rulemaking hearings, it may be efficient of the court's time to require all direct and rebuttal expert testimony to be submitted in written form as carefully crafted expert disclosures with clear explanation of opinions and bases a suitable length of time before trial. Such disclosures already are required under the rules, but they must be admissible if they **[\*651]**are to be entered into the record as expert testimony. At trial, experts would be cross-examined by the parties (with strict time limits) and as needed by the court as to their disclosed opinions, but experts would not give direct oral testimony by questions from counsel in the traditional manner. In my experience, in large multi-party cases such as rulemaking hearings, this can be efficient of the court's time. An example of this occurred in a general water rights adjudication proceeding in Arizona, in which many parties retained experts and submitted expert disclosures. In that instance, the trial court was able to hear all of the parties' experts over a ten-day evidentiary hearing that included many site visits, heated discussions, and a follow-up supplemental evidentiary hearing. [[126]](#footnote-127)126

Improved CE and training for expert witnesses in the water courts should be required and enforced, whether one is a registered professional engineer, a certified geologist, or neither. Ethics training should asl be required as part of CE for expert witnesses, including the topic of adversarial bias. Practicing attorneys have certain minimum CE requirements, including ethics training. A parallel CE requirement for testifying experts would be appropriate, especially because, in ***Colorado***, there are currently no CE requirements for practicing geologists or engineers.

Mandatory CE should also be required for biannual renewal of PE registration by the ***Colorado*** State Board of Licensure for Architects, Professional Engineers and Professional Land Surveyors (a division of DORA).

These changes to the Water Court Rules and to CE training for testifying experts are suggested as an evolutionary step forward, building upon the innovations of the 2009 rule revisions. After ten years of case experience under the 2009 rule innovations, and fifty years following the 1969 Act, I believe it is time once again for a review of expert practice in the water courts. These, and perhaps other, innovations to the rules, coupled with improved training and CE for testifying experts and more emphasis on experts' responsibilities to the court, would lead to greater efficiency and accuracy in decision making by the water courts.

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**End of Document**

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