APPENDIX A
Court Documents

In re the GENERAL ADJUDICATION OF ALL RIGHTS TO USE WATER IN the GILA RIVER SYSTEM AND SOURCE

Nos. WC-90-0001-IR, WC-90-0001-IR, WC-90-0002-IR, WC-90-0003-IR, WC-90-0004-IR, WC-90-0005-IR, WC-90-0006-IR, WC-90-0007-IR, WC-79-0001, WC-79-0002, WC-79-0003, WC-79-0004

Supreme Court of Arizona

175 Ariz. 382*; *857 P.2d 1236*; *1993 Ariz. LEXIS 60*; *144 Ariz. Adv. Rep. 17

July 27, 1993

SUBSEQUENT HISTORY: Related proceeding at *San Carlos Apache Tribe v. Superior Court, 193 Ariz. 195, 972 P.2d 179, 1999 Ariz. LEXIS 5 (Ariz., 1999)*
Appeal after remand at *In re General Adjudication of All Rights to Use Water in the Gila River Sys. & Source, 198 Ariz. 330, 9 P.3d 1069, 2000 Ariz. LEXIS 94 (Ariz., 2000)*

PRIOR HISTORY: [***1] Maricopa County Nos. W-1, W-2, W-3, W-4 (Consolidated)
In re General Adjudication of All Rights to Use Water in the Gila River Sys. & Source, 171 Ariz. 230, 830 P.2d 442, 1992 Ariz. LEXIS 25 (Ariz., 1992)

DISPOSITION: REMANDED

CASE SUMMARY:

PROCEDURAL POSTURE: After hearings to determine whether underground water was to be included in a river system and source, appellant cities filed an interlocutory appeal in a trial court in Maricopa County (Arizona) asking the trial court to exclude groundwater from the adjudication. The trial court issued an order stating that groundwater was included in the river system and source if it was a stream's subflow. The cities appealed.

OVERVIEW: Cities and others filed an action under *Ariz. Rev. Stat. § 45-251 et seq.* to determine the extent and priority of the rights of all persons to use water in a river system and source. Hearings were held on the relationship between surface water and percolating groundwater. Following the hearings, the cities filed a motion asking the trial court to exclude groundwater from the adjudication. The trial court issued an order stating that the 50 percent/90 day rule stating that percolating underground water was appropriable if the volume of stream depletion reached 50 percent or more of the total volume pumped during 90 days of continuous pumping. On appeal, the court held that the 50 percent/90 day rule did not apply because it was inconsistent with prior case law which held that percolating groundwater was not subject to appropriation.

OUTCOME: The court vacated the trial court's order in part and remanded the case.

LexisNexis(R) Headnotes

Governments > State & Territorial Governments > Water Rights
Real Property Law > Water Rights > Beneficial Use
[HN1] See *Ariz. Rev. Stat. § 45-141(A).*

Governments > State & Territorial Governments > Water Rights

[HN2] The purpose of a general stream adjudication under title 45 of Arizona Revised Statutes is to determine the rights of all persons to use the waters of a river system and source. *Ariz. Rev. Stat. § 45-252(A)*. "River system and source" is defined as all water appropriable under *Ariz. Rev. Stat. § 45-141* and all water subject to claims based upon federal law. *Ariz. Rev. Stat. § 45-251(4)*.

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JUDGES: En Banc. Feldman, Chief Justice. Moeller, V.C.J., Corcoran and Zlaket, JJ., and William E. Druke, Court of Appeals Chief Judge, concur. Martone, J., did not participate in the determination of this matter; pursuant to Ariz. Const. art. VI, § 3, the Honorable William E. Druke, Chief Judge of Division [***5] Two, Arizona Court of Appeals, was designated to sit in his stead.

OPINION BY: FELDMAN

OPINION

[*384] [**1238] **OPINION**

This appeal presents the second of six issues accepted for interlocutory review on December 11, 1991. We decide today whether the trial court erred in adopting a test to determine whether the underground water known as subflow is appropriable under *A.R.S. § 45-141*. We have jurisdiction pursuant to *A.R.S. § 45-252* and *Ariz. Const. art. 6, § 5(3)*.

FACTS AND PROCEDURAL HISTORY

This case is a consolidated general adjudication brought under *A.R.S. § 45-251 et seq.* to determine the extent and priority of the rights of all persons to use water in the Gila River system and source. For the full procedural history of the case, see *Arizona v. San Carlos Apache Tribe of Arizona, 463 U.S. 545, 103 S. Ct. 3201, 77 L.Ed.2d 837 (1983)*; *United States v. Superior Court, 144 Ariz. 265, 270-71, 697 P.2d 658, 663-64 (1985)*, *In re Rights to the Use of the Gila River, 171 Ariz. 230, 232-33, 830 P.2d 442, 444-45 (1992)*. For the present opinion, [***6] the relevant facts are brief.

For five days in October 1987, the trial court held hearings on the relationship between surface water and groundwater. [*385] [**1239] Hydrologists and hydrological engineers testified and submitted reports on the relation between ground and surface water in general, and in the San Pedro and Santa Cruz watersheds in particular. The hearings were for the general education of all parties and the court, but the material adduced at the hearing was to be considered evidence on which the court could rely when appropriate.

Following the hearings, several cities [1] filed a Motion to Exclude Wells From the General Adjudication, asking the trial court to exclude from the adjudication all wells pumping percolating groundwater, and to include only those wells pumping surface flow and subsurface flow, within the meaning of *Maricopa County Municipal Water Conservation District No. One v. Southwest Cotton Co., 39 Ariz. 65, 4 P.2d 369 (1931)* ("*Southwest Cotton*"). The trial court decided to use the cities' motion, and the information developed at the hearings, as a vehicle to resolve several surface water and [***7] groundwater issues. Thus, in January 1988, the trial court ordered the parties to brief eight specific questions it believed it could decide as a matter of law based on the evidence adduced at the October 1987 hearings. In May 1988, the trial court heard argument and in September it issued its order answering those questions.

> 1 Those cities were Chandler, Tempe, Mesa, Scottsdale, Glendale, Peoria, Goodyear, Casa Grande, Avondale, Nogales, and Prescott.

One of the eight questions the trial court answered in its September order was:

> Is ground water included within the phrase "river system and source" as it is used in *A.R.S. §§ 45-141* and *45-251(4)*, and if so, to what extent is it included? [2]

The trial court concluded that underground water is included in the river system and source if it is a stream's subflow, as that term is used in *Southwest Cotton*. The effect of this ruling was to declare that groundwater pumpers extracting water within the court's definition of "subflow" were diverting water appropriable [***8] under *A.R.S. § 45-141(A)*. Therefore, their rights to that water would depend on the priority of their appropriation, rather than on an owner's right to remove water percolating under the surface of the owner's land.

2 *A.R.S. § 45-141(A)* reads:

> [HN1] The waters of all sources, flowing in streams, canyons, ravines or other natural channels, or in definite underground channels, whether perennial or intermittent, flood, waste or surplus water, and of lakes, ponds and springs on the surface, belong to the public and are subject to appropriation and beneficial use as provided in this chapter.

The court then concluded that certain wells withdrawing water from the younger alluvium of a stream basin should be presumed to be pumping appropriable subflow. The court instructed the Department of Water Resources ("DWR") to designate such wells in its hydrographic survey reports [3] as pumping appropriable subflow if:

> As to wells located in or close to that younger alluvium, the volume of stream depletion would reach 50% or more [***9] of the total volume pumped during one growing season for agricultural wells or during a typical cycle of pumpage for industrial, municipal, mining, or other uses, assuming in all instances and for all types of use that the period of withdrawal is equivalent to 90 days of continuous pumping for purposes of technical calculation.

The court acknowledged that this test (the "50%/90 day rule") appeared to be somewhat arbitrary but explained it was essential for use in instructing DWR in the preparation of its hydrographic survey reports. Well owners would be allowed to prove that their wells were not pumping subflow at the time of their evidentiary hearing.

3 These hydrographic survey reports are to be prepared by DWR pursuant to *A.R.S. § 45-256* as part of its role as technical advisor to the trial court.

Many parties sought review of this ruling pursuant to this court's Special Procedural Order Providing for Interlocutory Appeals and Certifications, filed September 26, 1989. We granted review and framed the issue [***10] as follows:

> [*386] [**1240] Did the trial court err in adopting its 50%/90 day test for determining whether underground water is "appropriable" under *A.R.S. § 45-141*?

THE ISSUE

This issue arises from the way Arizona water law has developed from territorial days. Those seeking a detailed history of the evolution of Arizona water law, going back to the organization of the Arizona Territory, are referred to John D. Leshy & James Belanger, Arizona Law Where Ground and Surface Water Meet, 20 Ariz. St.L.J. 657 (1988). As will be seen below, rights associated with water found in lakes, ponds, and flowing streams -- surface water -- have been governed by the doctrine of prior appropriation. This doctrine developed in the western part of the country where the common law riparian rights doctrine was unsuited to prevailing arid conditions. On the other hand, underground water has been governed by the traditional common law notion that water percolating generally through the soil belongs to the overlying landowner, as limited by the doctrine of reasonable use. *Id.*

This bifurcated system of water rights was not unique to Arizona. It was typical [***11] of western states until around the turn of the twentieth century. At that time, scientific investigation was revealing that most underground water is hydraulically connected to surface water. As scientific knowledge progressed, most states revised their water laws to provide for unitary management of hydraulically connected underground and surface water. Arizona, however, did not, and continues to adhere to a bifurcated system of water rights, with compelling implications for general stream adjudications. *Id.*

[HN2] The purpose of a general stream adjudication under title 45 is to determine the rights of all persons to use the waters of a river system and source. *A.R.S. § 45-252(A)*. "River system and source" is defined as "all water appropriable under [*A.R.S.] § 45-141* and all water subject to claims based upon federal law." *A.R.S. § 45-251(4)*. Thus, basic to this case is the extent to which water pumped from wells must be treated as appropriable under *§ 45-141* or, conversely, as groundwater excluded from the legal rules applying to prior appropriation. The need to resolve the question early in the proceeding impelled us to grant review.

HISTORICAL PERSPECTIVE

We start with [***12] *Southwest Cotton*, this court's early and most important attempt to enunciate the relative rights of groundwater and surface water users. The court's comment in that case applies to the present dispute:

> The case is one of the most important which has ever come before this court, involving as it does not only property interests of [great] value . . . but also a declaration of legal principles which will in all probability determine and govern to a great extent the course of future . . . development within the arid regions of Arizona. The real question involved is the law applicable to the relative rights to the ownership and use of the subterranean waters of the state as against those of the surface waters.

39 Ariz. at 71, 4 P.2d at 372.

Southwest Cotton involved a suit by Southwest Cotton Company and others ("Southwest Cotton") against Maricopa County Municipal Water Conservation District No. 1 and others ("Conservation District"). Southwest Cotton owned a large tract of land west of Phoenix. It drilled almost one hundred wells in and around the Agua Fria River bed [4] to irrigate 19,000 acres. In 1925, plans for a dam on [***13] the Agua Fria River upstream of Southwest Cotton's development matured, and the Conservation District floated bonds to finance the project. Southwest Cotton sued to enjoin the project, fearing that the upstream [*387] [**1241] dam would prevent water from reaching the downstream wells.

> 4 The Agua Fria River flowed only intermittently. Southwest Cotton's wells were located in an area roughly ten miles wide and twenty miles long. Some were in the river bed, and others ranged from a few feet to six miles from the river.

In the trial court, Southwest Cotton argued that the water it pumped was subject to appropriation under the predecessor of *A.R.S. § 45-141(A)*. [5] The trial court ruled for Southwest Cotton, holding that the water was appropriable as water flowing in definite underground channels.

> 5 Southwest Cotton also claimed rights to a surface diversion in connection with a tunnel and canal system at what was known as the Marinette heading.

[***14] On appeal, Southwest Cotton advanced three theories: (1) percolating underground water was appropriable; (2) water running in underground channels was appropriable; and (3) subflow of the Agua Fria River was appropriable. This court decided to treat all issues as matters of first impression. First, it addressed Southwest Cotton's claim that percolating groundwater is appropriable. At the time of *Southwest Cotton*, percolating water was defined generally as water that passes through the ground and does not form part of a body of water or a water course. 2 Clesson S. Kinney, The Law of Irrigation and Water Rights § 1188, at 2152 (2d ed. 1912). It was further classified with reference to the streams or other bodies of water to which it was tributary. "Diffused percolations" were not tributary to any definite surface or underground stream or body of water. *Id.* "Percolating waters tributary to surface water" were, as the name implies, "waters which infiltrate their way through the adjoining ground to some surface water course or other body of surface water." *Id.* § 1193, at 2162.

The *Southwest Cotton* court examined Arizona statutes from 1864 and its previous decisions [***15] and reaffirmed its prior holding that percolating subterranean water was not subject to appropriation. *39 Ariz. at 84, 4 P.2d at 376*. Language in the opinion makes it clear that the court meant that all percolating water, however classified, was not subject to appropriation. While distinguishing certain California cases on which Southwest Cotton relied, the court stated:

> Whether [the water underlying Southwest Cotton's land] be diffused percolations in the common law sense of the term . . ., or whether it be percolating waters whose extraction will tap other waters, . . . is immaterial in this instance, for neither class is subject to appropriation under the law of Arizona.

Id. at 100, 4 P.2d at 382. [6]

> 6 Any decision as to what law applied to percolating water was left for another day. *Id. at 83-84, 4 P.2d at 376*. That day arrived more than twenty years later. *See Bristor v. Cheatham, 75*

Ariz. 227, 255 P.2d 173 (1953), which established the right of the surface owner to reasonable use of the water percolating under his property.

[***16] The court also addressed Southwest Cotton's argument that its water came from underground streams. The court rejected that argument because there was insufficient evidence to show that Southwest Cotton's wells tapped underground channels with known and definite banks from which Arizona law allowed appropriations. *Id. at 95, 4 P.2d at 380*.

Finally, the court addressed the argument that Southwest Cotton was pumping appropriable subflow of the Agua Fria River. The court defined "subflow" as

> those waters which slowly find their way through the sand and gravel constituting the bed of the stream, or the lands under or immediately adjacent to the stream, and are themselves a part of the surface stream.

Id. at 96, 4 P.2d at 380.

> In almost all cases the so-called subflow is found within, or immediately adjacent to, the bed of the surface stream itself.

Id. at 97, 4 P.2d at 381.

Subflow "physically . . . constitute[s] a part of the surface stream itself, and [is] simply incidental thereto." *Id. at 96, 4 P.2d at 380*. It is subject to the same rules of appropriation as the surface stream itself. *Id. at 97, 4 P.2d at 380-81*.

[*388] [**1242] The court [***17] set forth a test for determining whether underground water is appropriable subflow. First, it wrote:

> The best test which can be applied to determine whether underground waters are as a matter of fact and law part of the surface stream is that *there cannot be any abstraction of the water of the underflow without abstracting a corresponding amount from the surface stream*, for the reason that the water from the surface stream must necessarily fill the loose, porous material of its bed to the point of complete saturation before there can be any surface flow.

Id. at 96, 4 P.2d at 380 (emphasis added).

In the next paragraph, the court wrote:

> Not only does [subflow] move along the course of the river, but it percolates from its banks from side to side, and the more abundant the surface water the further will it reach in its percolations on each side. But, considered as strictly a part of the stream, the test is always the same: *Does drawing off the subsurface water tend to diminish appreciably and directly the flow of the surface stream?* If it does, it is subflow, and subject to the same rules of appropriation as the surface stream itself; if it does not, then, [***18] although it may originally come from the waters of such stream, it is not, strictly speaking, a part thereof, but is subject to the rules applying to percolating waters.

Id. at 96-97, 4 P.2d at 380-81 (emphasis in original).

Concluding that there was no evidence that Southwest Cotton's pumping directly or appreciably diminished the flow of the river, the court reversed and remanded the case for a new trial. *Id. at 99, 106, 4 P.2d at 381, 384*.

Until *Bristor v. Cheatham, 73 Ariz. 228, 240 P.2d 185 (1952)* ("*Bristor I*"), this court consistently applied *Southwest Cotton's* rule that percolating groundwater is not subject to appropriation. In *Bristor I*, the court held by a 3-2 margin that percolating water was subject to appropriation. The court granted rehearing, however, and fourteen months later reversed itself by a 3-2 margin. In *Bristor v. Cheatham, 75 Ariz. 227, 255 P.2d 173 (1953)* ("*Bristor II*"), the majority reaffirmed our prior holdings that percolating water is not subject to appropriation. Arizona's courts have followed *Bristor II* to this day.

DISCUSSION

[***19] The parties in this appeal generally agree that *Southwest Cotton* is at the heart of the issue before us. One group argues that *Southwest Cotton's* concept of subflow is narrow, and that the 50%/90 day rule is too broad, because it includes wells that pump underground water not appropriable under *A.R.S. § 45-141(A)*. Another group argues that *Southwest Cotton's* concept of subflow is broad, and that the 50%/90 rule is too narrow, because it fails to include all wells that pump appropriable subflow. The third group argues that the trial court was correct. Although it seems to agree that the 50%/90 day rule is not faithful to *Southwest Cotton*, the third group contends that the trial court's order should not be

disturbed because it merely creates a rebuttable presumption. We address this argument first.

A. The presumption

The 50%/90 day rule was formulated to instruct DWR in the preparation of hydrographic survey reports, and merely creates a rebuttable presumption that wells meeting the test are pumping subflow. Nonetheless, if the test is defective, its use would adversely affect the adjudication. It would plant errors in every hydrographic survey report, which [***20] would have to be litigated according to the procedures set out in the Rules for Proceedings Before the Special Master, Rules 6.00-16.00. This would exacerbate an already lengthy and costly process. Perhaps even more significantly, use of a flawed test for identifying wells pumping subflow could cause significant injustice. Many surface owners unable to mount a challenge could effectively lose their right to pump percolating groundwater, simply because their wells were improperly presumed to be pumping [*389] [**1243] appropriable subflow. Considering the time, expense, and importance of accurate hydrographic survey reports, and the complex lawsuits over their correctness, it would be a senseless waste to use a flawed presumption for identifying wells pumping subflow.

B. Applying the rule of Southwest Cotton

1. *Stare decisis*

We now determine whether the trial court's 50%/90 day rule accurately reflects *Southwest Cotton's* subflow rationale. We perceive our role as interpreting *Southwest Cotton*, not refining, revising, correcting, or improving it. We believe it is too late to change or overrule the case. More than six decades have passed since *Southwest* [***21] *Cotton* was decided. The Arizona legislature has erected statutory frameworks for regulating surface water and groundwater based on *Southwest Cotton*. Arizona's agricultural, industrial, mining, and urban interests have accommodated themselves to those frameworks. *Southwest Cotton* has been part of the constant backdrop for vast investments, the founding and growth of towns and cities, and the lives of our people. Of course, this court is not absolutely bound by *stare decisis* and may change judge-made law, especially when the need for change is apparent, the error or confusion in previous decisions is evident, and change is possible without causing significant damage. We have done so in the recent past. *See Wiley v. Industrial Commission, 174 Ariz. 94, 847 P.2d 595 (1993)*. We do not do so lightly, however, or in the absence of compelling reasons. *State v. Huerta, 175 Ariz. 262, 855 P.2d 776 (1993)*; *cf. State v. Lara, 171 Ariz. 282, 285, 830 P.2d 803, 806 (1992)*.

If this principle applies to ordinary cases, it must be applied with [***22] particular care when the prospective effect of change threatens important vested rights and may affect every Arizonan's well-being. Thus, even though *Southwest Cotton* may be based on an understanding of hydrology less precise than current theories, it would be inappropriate to undo that which has been done in the past. Instead, we will attempt only to resolve as best we can the ambiguities and uncertainties left by that decision. Given the inexact nature of the "direct and appreciable diminution" test laid down by *Southwest Cotton*, that in itself is no small task.

2. *Application*

Those who argue that the 50%/90 day rule is too narrow suggest that *Southwest Cotton's* test is very broad. They argue that pumping underground water from a tributary aquifer [7] causes direct stream depletion, either by intercepting water that otherwise would reach the stream or by dewatering an area, thereby inducing water to flow from the stream to fill the void. Such depletion is "appreciable," the argument goes, if it is "[c]apable of being estimated . . . or recognized . . .[;] perceptible." Citing Oxford English Dictionary (2d ed. 1989). These parties contend that any well pumping [***23] from a tributary aquifer is pumping subflow if it causes any measurable stream depletion in a period of one or more decades. [8] Viewed outside the context in which the *Southwest Cotton* test was formulated, that interpretation is plausible. Viewed in context, however, it clearly is too expansive from both geographical and time standpoints.

7 A tributary aquifer is an aquifer having a direct hydraulic connection with a stream or with another aquifer that has such a connection.

8 The lead brief for those arguing that the test is too narrow suggests a period of ten years. The brief filed by the Nature Conservancy suggests a period of forty years. Both briefs allow for exclusion of wells that pump de minimis amounts of water or that have de minimis impact on surface streams.

When *Southwest Cotton* was decided, subflow was a well known water law concept. The primary authority on which the *Southwest Cotton* court relied concerning subflow was 2 Kinney, *supra* § 1161. Kinney addressed the concept of [***24] subflow in Chapter 60, entitled "Subterranean Water Courses." He subdivided subterranean water courses into two general categories, [*390] [**1244] known and unknown. Known subterranean water courses were those in which the channel had been identified. Unknown courses were those in which the channel had not been identified. *Id.* § 1155, at 2098-99. Known subterranean water courses were further subdivided into independent or dependent. Independent courses were those that flowed "independent of the influence of any surface streams." *Id.* § 1156, at 2100. Dependent courses were "waters . . . dependent for their supply upon the surface streams, or are the 'underflow,' 'sub-surface flow,' 'subflow,' or 'undercurrent,' as they are at times called, of surface streams." *Id.* § 1161, at 2106. Kinney's definition of subflow was the one used in *Southwest Cotton. See 39 Ariz. at 96, 4 P.2d at 380*. [9]

> 9 *See also* Black's Law Dictionary 1425 (6th ed. 1990), defining "subflow" as "[t]hose waters which slowly find their way through sand or gravel constituting bed of a stream, or lands under or immediately adjacent to [a] stream."

[***25] Kinney specifically discussed subflow in the context of intermittent streams, such as the Agua Fria River, at issue in *Southwest Cotton*. He explained that a large volume of water flows through the sand and gravel underlying most streams in arid regions. During dry seasons, the surface of these streams may be dry, but water flows underneath the surface. This underground water is not a separate underground stream but still a part of the surface stream. 2 Kinney, *supra* § 1161, at 2106-10. Furthermore, speaking again about intermittent streams, Kinney wrote:

> [W]aters, in order to constitute the underground flow of surface streams, must be connected with the stream and strictly confined to the river bottom and moving underground, as was stated in a California case, "in connection with it, and a course with a space reasonably well defined." In other words, the water must be within the bed of the surface stream itself. Otherwise such underground waters must be classified with percolating waters, hereinafter discussed.

Id. § 1161, at 2110 (footnotes omitted).

In his later discussion of percolating water, Kinney wrote:

> Our second class of percolating waters we will [***26] define as those waters which infiltrate their way through the adjoining ground to some surface water course or other body of surface water.

Id. § 1193, at 2162 (footnote omitted). Kinney described what the parties in this case have referred to as tributary groundwater. He pointedly distinguished tributary groundwater from subflow:

> [Percolating waters tributary to surface waters] differ from the underflow of surface streams in the fact that they have not yet reached the channels of the water courses to which they are tributary; while, upon the other hand, the underflow of surface streams have reached these channels and are therefore dealt with as component parts of such streams.

Id. (footnote omitted).

Thus, Kinney defined subflow narrowly and specifically distinguished it from tributary groundwater. It is clear that we adopted that narrow definition in *Southwest Cotton*. The court's discussion of subflow, *39 Ariz. at 96-97, 4 P.2d at 380-81*, is a virtual paraphrase of large portions of Kinney's discussion in § 1161, at 2106-10. Furthermore, in its answering brief Southwest Cotton made essentially the same argument [***27] that is being made in this proceeding. In a section of its brief entitled "Underground Waters Tributary to or Dependent Upon Surface Streams Subject to Appropriation as Part of the Stream," Southwest Cotton argued that underground water that is hydraulically connected -- tributary -- to surface water should be considered part and parcel of the surface stream. As such, it should be subject to appropriation as waters of the stream. Brief of Appellees (Conservation District) at 199-200.

The court rejected that argument, holding that all types of percolating water were not subject to appropriation under Arizona law. *Southwest Cotton, 39 Ariz. at 84, 4 P.2d at 376*. Having so held, it is unreasonable [*391] [**1245] to suppose that the court then turned around and adopted a concept of subflow broad enough to include all underground water hydraulically connected to a surface stream. It seems clear that the court considered subflow and tributary groundwater to be two different classes of underground water. The former is subject to appropriation under the predecessor of *A.R.S. § 45-141(A)*; the latter is not.

The rehearing proceedings [***28] in *Southwest Cotton* further indicate the court's narrow view of subflow. In its petition for rehearing, Southwest Cotton argued that the court defined subflow too narrowly. It took issue with the use of the term "immediately" in the following portion of the opinion:

> The underflow, subflow, or undercurrent, as it is variously called, of a surface stream may be defined as those waters which slowly find their way through the

> sand and gravel constituting the bed of the stream, or the lands under or *immediately* adjacent to the stream, and are themselves a part of the surface stream.

39 Ariz. at 96, 4 P.2d at 380 (emphasis added). Southwest Cotton argued that neither Kinney nor any other text writer used the word "immediately" or any of its synonyms as a limitation on the word "adjacent." Petition for Rehearing at 22. In its opinion on rehearing, the court made no specific mention of this argument but essentially affirmed its original test for identifying subflow. *Maricopa County Mun. Water Conservation Dist. No. One v. Southwest Cotton Co., 39 Ariz. 367, 369, 7 P.2d 254, 254 (1932)*. [***29] Obviously, therefore, the court meant it when it said that in almost all cases "subflow is found within, or immediately adjacent to, the bed of the surface stream itself." *39 Ariz. at 97, 4 P.2d at 381*. Subflow is a narrow concept. Thus, all water in a tributary aquifer is not subflow.

We believe the *Southwest Cotton* court drew a line between subflow as part of the stream and water in the surrounding alluvium that is either discharging into the stream or being discharged by the stream. That line is relatively close to the stream bed, with variations depending on the volume of stream flow and other variables. Thus, if a well is drawing water from the bed of a stream, or from the area immediately adjacent to a stream, and that water is more closely related to the stream than to the surrounding alluvium, as determined by appropriate criteria, the well is directly depleting the stream. If the extent of depletion is measurable, it is appreciable. This is not an all-or-nothing proposition. For example, if the cone of depression [10] of a well has expanded to the point that it intercepts a stream bed, it almost certainly will be pumping [***30] subflow. At the same time, however, it may be drawing water from the surrounding alluvium. Thus, part of its production may be appropriable subflow and part of it may not. Even though only a part of its production is appropriable water, that well should be included in the general adjudication.

10 The cone of depression is the "funnel-shaped area around a well, where the water table has been lowered by the withdrawal of groundwater through the well." 6 Robert E. Beck, ed., Waters and Water Rights 503 (1991).

We believe that the trial court's approach is inconsistent with *Southwest Cotton*. The trial court instructed DWR to apply the 50%/90 day test to all wells located in or near the younger alluvium. The record shows, however, that in a given area the younger alluvium may stretch from ridge line to ridge line so that all wells in the valley would be in or near the younger alluvium. To say that all of an alluvial valley's wells may be pumping subflow is at odds with *Southwest Cotton's* statement that subflow [***31] is found within or immediately adjacent to the stream bed.

Likewise, the 50%/90 day "volume-time" test does not find its origin in *Southwest Cotton*. Given enough time, and with certain exceptions, all extractions from a tributary aquifer will cause a more-or-less corresponding depletion from stream flow volume. That, indeed, is the basis of the continuing controversy between groundwater pumpers and surface appropriators. *Southwest Cotton*, however, did not purport [*392] [**1246] to identify subflow in terms of an acceptable amount of stream depletion in a given period of time. It sought to identify subflow in terms of whether the water at issue was part of the stream or was percolating water on its way to or from the stream.

Furthermore, the actual time and volume elements adopted by the trial court are essentially arbitrary. Under the trial court's test, a pumper extracting 1,000 acre feet, diminishing stream flow by "only" 499 acre feet within 90 days, would be presumed to be pumping groundwater, whereas a well owner extracting 100 acre feet, depleting stream flow by 51 acre feet, would be presumed to be pumping surface water. Nothing in *Southwest Cotton* or [***32] the record in this proceeding justifies so arbitrary a classification. The same, of course, is true of application of the 90-day time period. Why not 75 or 100 days?

Whether a well is pumping subflow does not turn on whether it depletes a stream by some particular amount in a given period of time. As we stated above, it turns on whether the well is pumping water that is more closely associated with the stream than with the surrounding alluvium. For example, comparison of such characteristics as elevation, gradient, and perhaps chemical makeup can be made. Flow direction can be an indicator. If the water flows in the same general direction as the stream, it is more likely related to the stream. On the other hand, if it flows toward or away from the stream, it likely is related to the surrounding alluvium. The present record certainly allows neither the trial court nor us to identify a definitive set of criteria. Furthermore, it also is likely that differences in geology and hydrology from location to location may require that different criteria be given more or less emphasis, depending on the area under analysis. The record allows neither the trial court, nor us, to make [***33] those determinations.

We conclude, therefore, that the 50%/90 day test for identifying wells presumed to be pumping subflow is inconsistent with *Southwest Cotton* and should not be used.

3. *The burden of proof*

The trial court's 50%/90 day rule created a presumption that wells meeting the test are pumping appropriable water. The burden of proof then fell on well owners to prove that their wells did not pump appropriable water. Those arguing that the 50%/90 day test is too narrow point out that under Arizona law underground water is presumed to be percolating and that one claiming otherwise has the burden of proving the claim by clear and convincing evidence. *Neal v. Hunt, 112 Ariz. 307, 311, 541 P.2d 559, 563 (1975)*; *Southwest Cotton, 39 Ariz. at 85, 4 P.2d at 376*. Thus, they conclude, the trial court's order improperly shifted to well owners the burden of proving that their wells do not pump appropriable water. We disagree. If DWR uses the proper test and relies on appropriate criteria for determining whether a well meets the test, its determination that a well is pumping appropriable [***34] subflow constitutes clear and convincing evidence. It is consistent with Arizona law, then, to require the well owner to come forward with evidence that DWR is wrong.

4. *The future*

Finally, we recognize that the line between surface and groundwater drawn by the *Southwest Cotton* court and reaffirmed by this court today is, to some extent, artificial and fluid. As discussed above, however, we do not feel free to redraw or erase that line. It is important to remember that the *Southwest Cotton* court did not create an all-encompassing set of common law principles. It purported, instead, to interpret the relevant statutes codifying the doctrine of prior appropriation and identifying the water sources to which the doctrine applied. Those statutes remain relatively intact. *See A.R.S. § 45-141*. Southwest Cotton argued at the time for a different interpretation of the statutes and the Arizona Constitution. Since *Southwest Cotton*, many have criticized Arizona's adherence to a bifurcated system of water management. *See* Leshy & Belanger, *supra*, at 657-60. Now, sixty years later, [*393] [**1247] similar arguments are made that *Southwest Cotton* [***35] misinterpreted our statutes and constitution. *See id.* at 767-90. We recognize compelling arguments in favor of unified management of Arizona's water resources. Nonetheless, in the decades since *Southwest Cotton* was decided, the Arizona Legislature has not significantly altered the opinion's reach.

Southwest Cotton's concept of subflow added marginally to the statutory definition of water subject to appropriation, but we do not propose to rewrite the statute further by broadening the concept of subflow. We believe the trial court's 50%/90 day rule expands the clear words of *A.R.S. § 45-141(A)* to include not only waters flowing in streams but, potentially, waters pumped any place in the younger alluvium. The court's order does not explain the rule's derivation. The 50%/90 day rule does not comport with the tests laid down in *Southwest Cotton*. Water may be considered appropriable underflow if the "abstraction" by pumping results in "abstracting a corresponding amount from the surface stream." Considering subflow as "strictly a part of the stream, the test is always the same: *Does drawing off the subsurface water tend to diminish appreciably and directly the flow* [***36] *of the surface stream?" 39 Ariz. at 97, 4 P.2d at 380* (emphasis in original).

Thus, we reaffirm *Southwest Cotton's* narrow concept of subflow. We realize this does not solve the problems of equitably apportioning all available water in the state between conflicting interests and claims of groundwater users and surface appropriators. We believe, however, that in this area of the law, as much or more than any other, any appropriate change in existing law must come from the legislature. *See* Arizona Groundwater Code, Title 45, ch. 2; *Chino Valley v. City of Prescott, 131 Ariz. 78, 638 P.2d 1324 (1981)*. That is as it should be. As we stated in *Arizona Public Service Co. v. Long, 160 Ariz. 429, 436, 773 P.2d 988, 995 (1989)*:

> Regulation of water use, . . . especially in a desert state, does not lend itself to case-by-case definition. In this field, we not only confer private rights and interests but deal in the very survival of our society and its economy. Simply put, there is not enough water to go around. All must compromise and some [***37] must sacrifice. Definition of those boundaries is peculiarly a function for the legislature. It is plainly not a judicial task. Accordingly, we must look to the legislature to enact the laws they deem appropriate for wise use and management.

D. Comprehensiveness Requirement

The United States is a party to this case under the McCarran Amendment, which gives consent to suits against the United States in state court adjudications that embrace "rights to the use of water in a river system or other source." *43 U.S.C. § 666(a)*. The United States argues that unless this adjudication includes all water hydrologically connected to the Gila River system, it will not be comprehensive enough to satisfy the McCarran

Amendment requirement that it embrace all rights to the use of water in the river system or other source. At oral argument, the United States also asserted that the trial court in this case cannot exclude wells having only a de minimis effect on the river system. We disagree.

The McCarran Amendment recognizes that any decree from a water rights adjudication would be of little value unless it joined all parties owning rights to a stream [***38] or water source, including the United States. According to Senator McCarran, who introduced the bill and chaired the reporting committee:

> S. 18 is not intended . . . to be used for any other purpose than to allow the United States to be joined in a suit wherein it is necessary to adjudicate all of the rights of various owners on a given stream. This is so because unless all the parties owning or in the process of acquiring water rights on a particular stream can be joined as parties defendant, any subsequent decree would be of little value.

United States v. District Court in and for Eagle County, Colo., 401 U.S. 520, 525, 91 [*394] [**1248] *S. Ct. 998, 1002, 28 L.Ed.2d 278 (1971)* (quoting from S.Rep. No. 755, 82d Cong., 1st Sess., at 9 (1951)). The McCarran Amendment was not intended to impose on the states a federal definition of "river system or other source." Rather, as the Court held in *Colorado River Water Conservation District v. United States, 424 U.S. 800, 819, 96 S. Ct. 1236, 1247, 47 L.Ed.2d 483 (1976)*:

> The consent to jurisdiction [***39] given by the McCarran Amendment bespeaks a policy that recognizes the availability of comprehensive state systems for adjudication of water rights as the means for achieving [the goal of avoiding piecemeal adjudication of interdependent water rights by resolving them in a single unified proceeding].

The United States has cited no authority supporting its reading of the McCarran Amendment, [11] but there is contrary precedent. In *United States v. Oregon Water Resources Department, 774 F. Supp. 1568, 1578 (D.Ore.1991)*, the court wrote:

> Finally, the United States and the Tribe argue that because the adjudicative procedures of the State of Oregon do not call for simultaneous adjudication of rights to surface water and rights to groundwater within a given river system, the adjudication is not comprehensive within the meaning of the McCarran Amendment. The language of the McCarran Amendment does not support this construction, and the United States and the Tribe point to no provision in the legislative history and no case precedent, state or federal, in support of this construction of the McCarran Amendment.

This correctly states the law.

> 11 The United States provided this court with a copy of an unpublished decision of a California superior court in which the court granted a federal motion to dismiss on the ground that the proceeding was not comprehensive because it did not include groundwater users. We do not find that to be persuasive authority. In any event, the California court did not base its decision on what it perceived to be a rule of general application but on the peculiar facts of the case before it.

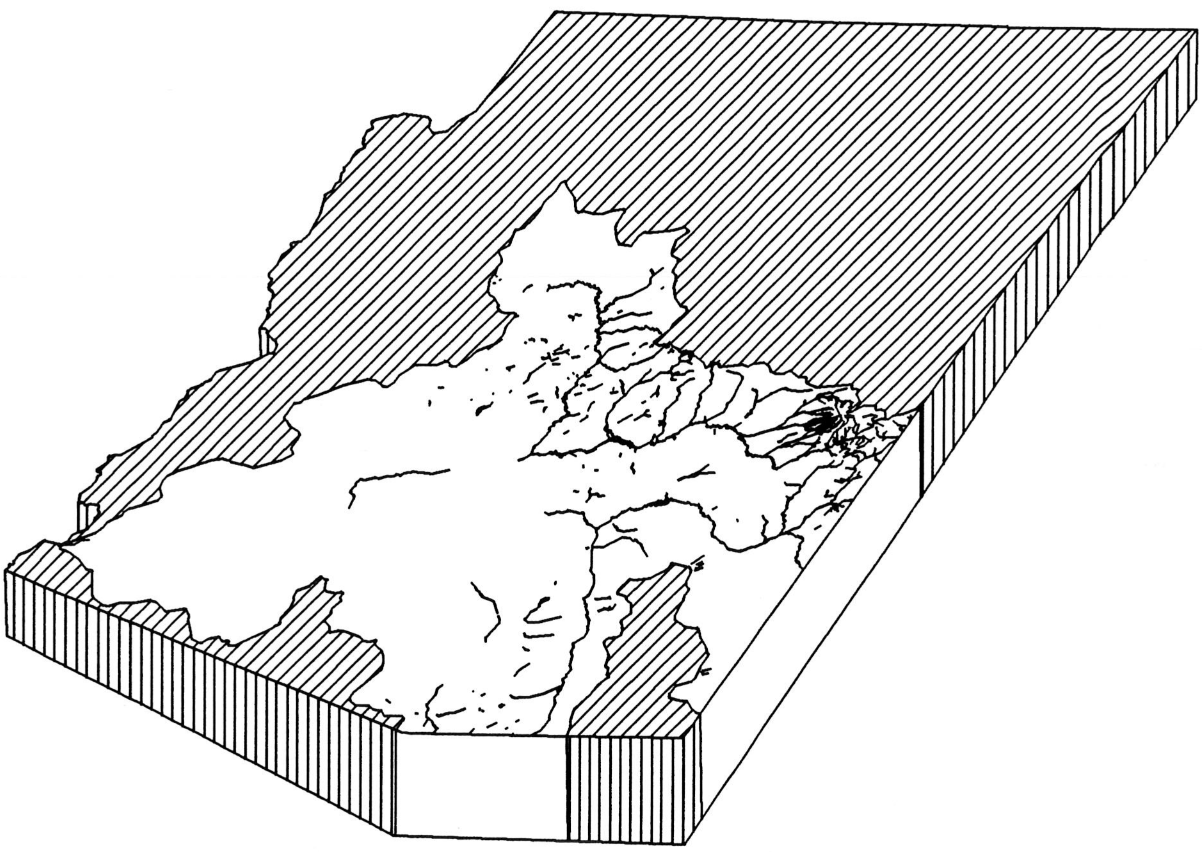
[***40] We believe that the trial court may adopt a rationally based exclusion for wells having a de minimis effect on the river system. Such a de minimis exclusion effectively allocated to those well owners whatever amount of water is determined to be de minimis. It is, in effect, a summary adjudication of their rights. A properly crafted de minimis exclusion will not cause piecemeal adjudication of water rights or in any other way run afoul of the McCarran Amendment. Rather, it could simplify and accelerate the adjudication by reducing the work involved in preparing the hydrographic survey reports and by reducing the number of contested cases before the special master. Presumably, Congress expected that water rights adjudications would eventually end. It is sensible to interpret the McCarran Amendment as permitting the trial court to adopt reasonable simplifying assumptions to allow us to finish these proceedings within the lifetime of some of those presently working on the case.

CONCLUSION

We vacate the portion of the trial court's September 8, 1988 order that formulated the 50%/90 day rule. We remand the matter to the trial judge to take evidence and, by applying the principles [***41] contained in this opinion, determine the criteria for separating appropriable subflow from percolating groundwater.

TECHNICAL ASSESSMENT OF THE ARIZONA SUPREME COURT INTERLOCUTORY APPEAL ISSUE NO.2 OPINION

In Re The General Adjudication of the Gila River System and Source



Arizona Department of Water Resources

December 15, 1993

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CHAPTER 1: INTRODUCTION

Arizona is unique among western states in its distinction between nonappropriable percolating groundwater and appropriable subsurface streamflow. The bifurcated system demands a determination of whether one's water is governed by the Groundwater Code or the Surface Water Code though neither the law nor the hydrology of the typical alluvial valley stream provides a clear dividing line between groundwater and surface water. This report, prepared by the Arizona Department of Water Resources (DWR), analyzes the problem of distinguishing between percolating groundwater and subsurface streamflow under this system, and suggests alternative criteria which may be used to make this determination in view of existing law.

The analysis begins in Chapter 2 with a brief review of standard groundwater hydrology. These principles, widely recognized in the fields of science and engineering, explain the relationship between the aquifer and the stream, and discusses the technical methods available to determine the impact of pumpage on streamflow. In Chapter 3, attention is turned to the recent opinion of the Arizona Supreme Court which attempts to define the hydrologic relationship between aquifers, pumping wells, and streams while simultaneously recognizing existing legal precedent and private property rights.[1] Here, the relationship between the legal concept of subflow and the technical means which may be employed to identify and delineate its extent are considered in detail. The alternative technical methods are compared to applicable provisions in the opinion, extracting from the mandate issued by the Court key criteria upon which to base a workable definition of the concept of appropriable subflow. By workable, DWR stresses that the definition must be a uniform standard which can be applied throughout the watershed. It should also be applicable across the entire Gila River system.

In Chapter 4, DWR describes an entirely new proposal for delineating the subflow of the surface stream that we believe is compatible with even the strictest interpretation of the opinion. In order to exclude tributary aquifers from the definition

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[1] *In re the General Adjudication of All Rights to Use Water in The Gila River System and Source*, ___ Ariz. ___, 857 P.2d 1236 (Filed July 27, 1993).

of subflow, particular attention is paid to the direction of flow of the underground water. The hydraulic connection between the percolating groundwater and the surface flow, if any, is also stressed as a primary factor in the determination. The method requires that each major adjudication watershed should be examined independently, because the specific geology, topography and cultural diversity of each region controls the hydrologic analysis. Examples include Aravaipa Canyon, where hard rock boundaries greatly reduce the existence of subflow under the specified criteria. In contrast, in the Palominas area of the San Pedro watershed, cultural activities have altered the natural elevation and flow direction of the underground water, increasing the existence of subflow.

Chapter 5 is a proposed plan of implementation for the criteria established in Chapter 4. This plan shows, by example, how the criteria will actually work in the study reaches of the San Pedro River watershed. The reader is cautioned that these examples are not a final analysis and may be subject to change when the final hydrographic survey reports (HSR) are produced. Nevertheless, every effort has been made to complete the examples in a manner which will accurately demonstrate the true nature of the criteria.

Chapter 6 is a summary of the report and DWR's conclusions regarding the merits of alternative methods of identifying and delineating subflow. The final portion of DWR's analysis consists of appendices, which supply substantial background materials supporting the conclusions drawn in the text. Persons evaluating this report are encouraged to examine the underlying data and compare it and the models generated from it with their own information sources.

The intent of this report is to assist in finding a means to uphold the letter and spirit of the Arizona Supreme Court's recent opinion on the definition of subflow, while at the same time applying sound principles of hydrology. This is a difficult task, as it attempts to draw a fixed, cultural line through a dynamic, natural system. The alternative criteria proposed in this report are all reasonable methods by which to make this important determination, ranging from the most rigorous scientific methods, to the simpler geographic methods, to the method proposed by DWR which seeks the least controversial path through the various provisions of the Supreme Court's ruling.

In the final analysis, however, the determination that a well is "more closely associated with the stream than with the surrounding alluvium" or that the well "directly and appreciably" affects the stream will always involve the exercise of judgment. That judgment must be left either to the courts or the legislature for final resolution.

CHAPTER 2: BASIC HYDROLOGIC PRINCIPLES

Hydrology is the study of the properties of water. It is a multi-disciplined science encompassing physics, chemistry, geology, geography and climatology. Like most sciences, the study of hydrology depends upon the acceptance of certain immutable principles. From these principles, theories and equations can be derived to predict, intuitively and mathematically, the course of water in motion.

This chapter reviews the hydrologic principles necessary to understand the relationship between water percolating through the earth and water moving with a stream. These concepts include: the types of surface water found in the West, the types of aquifers found in the West, the dynamic interaction of groundwater and surface water near the streambed, and the mathematical concepts, some derived over a century ago, which explain this relationship in mathematical terms.

2.1 HYDROLOGIC OVERVIEW

The alluvial basins of the arid West are integrated hydrologic systems composed of surface water and groundwater components. Water in these systems flows from areas of high elevation to areas of lower elevation along a path of greatest slope under the influence of gravity. Major perennial or intermittent streams occur in the central portion of the alluvial basin, occupying the lowest areas of the basin floor, flowing along the slope of the basin. The perennial or intermittent stream is typically surrounded by younger alluvium. Surface flow in the stream is derived from runoff from precipitation and groundwater discharge. Groundwater flows in unconsolidated and consolidated aquifers from the mountain fronts at the margins of the basin toward the center, occupied by the younger alluvium and the stream. Upon nearing the center of the basin in the vicinity of the younger alluvium, groundwater flows under the influence of the basin slope, in the same direction as the stream.

The physical character of groundwater and surface water in the vicinity of the younger alluvium is often identical. Surface water and groundwater in this area occupy the same geologic space and flow in the same direction along the slope of the basin. There is free interaction between groundwater and surface water; groundwater in the younger alluvium contributes to the surface flow and the surface flow recharges the younger alluvium. Distinguishing between groundwater and surface water in the vicinity of the younger alluvium in hydrologic terms to derive a legal standard is problematic and a byproduct of Arizona's bifurcated legal system.

2.2 STREAM TYPES

Surface water streams fall into one of three types: perennial, intermittent, or ephemeral. The type of stream is indicative of the extent of groundwater/surface water interactions taking place. Where streams have transitioned from perennial to intermittent or ephemeral since groundwater development began, pumpage has altered the aquifer-stream relationship. PLATE 1 shows the distribution of perennial and intermittent streams in the Gila River system.

Perennial streams discharge water continuously throughout the year. Their source of supply is normally comprised of both direct runoff from precipitation events or snowmelt, and baseflow derived from the discharge of groundwater into the stream. Gains to the stream occur when the water table in the adjacent aquifer is at or above the water level in the stream. Losses occur when the water table falls below the water level in the stream and the direction of seepage reverses. The stream begins to recharge the river aquifer. It is not uncommon for a perennial stream flowing under baseflow conditions to have both gaining and losing reaches, as shown by Figure 2-1. The gaining reaches represent areas where the amount of groundwater discharging into the stream is greater than natural losses and cultural diversions. Losing reaches are the areas where natural losses and cultural diversions are greater than groundwater discharge entering the stream. Where losing reaches are long enough to consume all of the baseflow, perennial stream conditions cease.

Intermittent streams discharge water for long periods of time, but seasonally. For example, an intermittent stream may flow all winter, every winter, but never flow continuously during the summer. During seasons when baseflow is maintained, groundwater is contributing to the stream. During seasons of discontinuous streamflow, natural and cultural losses may be greater than the contribution from groundwater, resulting in a losing stream. Or, the amount of groundwater discharge itself may have decreased due to natural or cultural uses. Figure 2-2 shows a typical seasonal cycle for intermittent streams interconnected with aquifers. During some seasons intermittent streams may be gaining streams, and during other seasons they may be losing streams. During seasons when there is no baseflow, intermittent streams may nevertheless retain an active groundwater subflow component where the

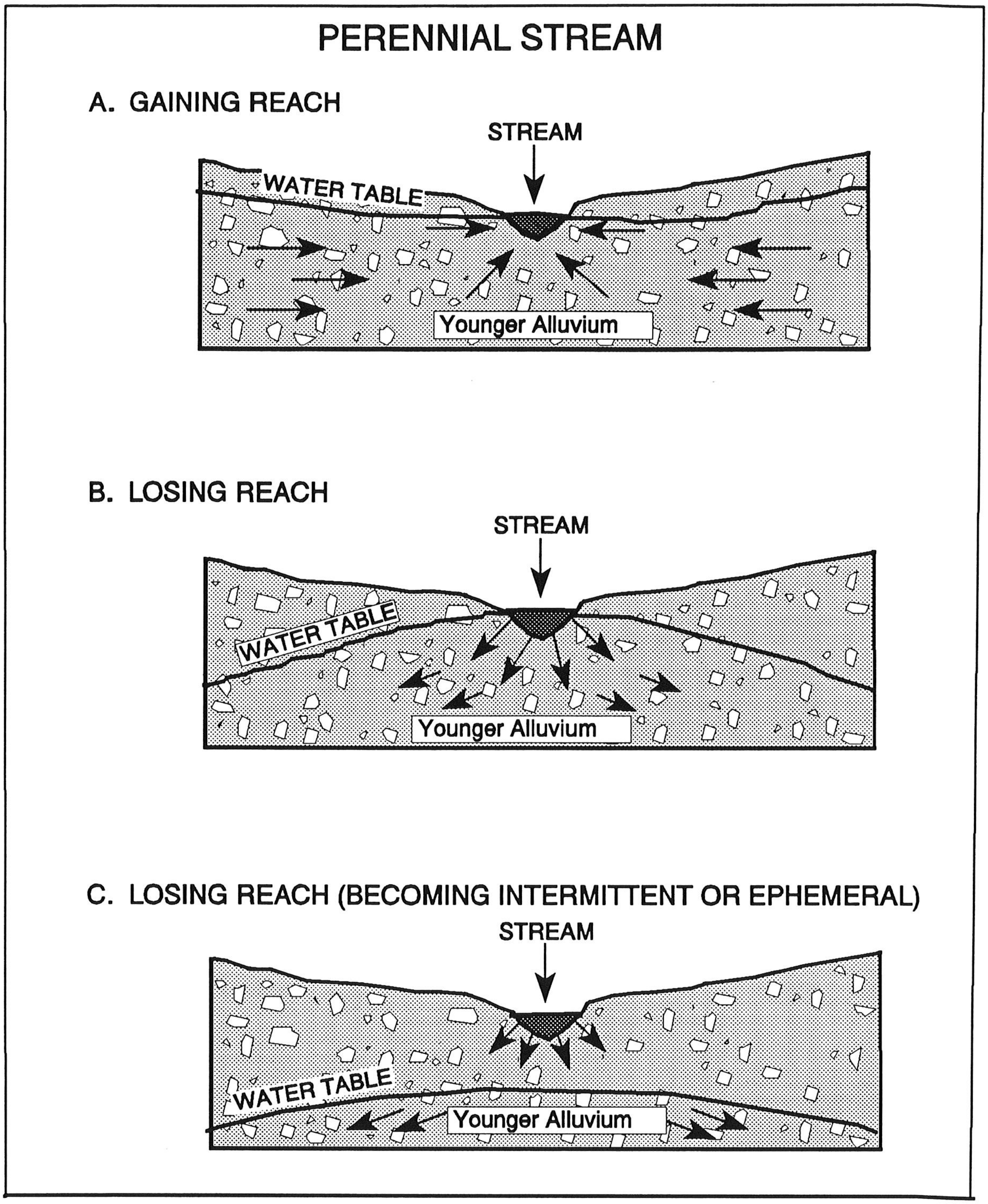

Figure 2-1. Perennial reaches and their relationship to the water table.

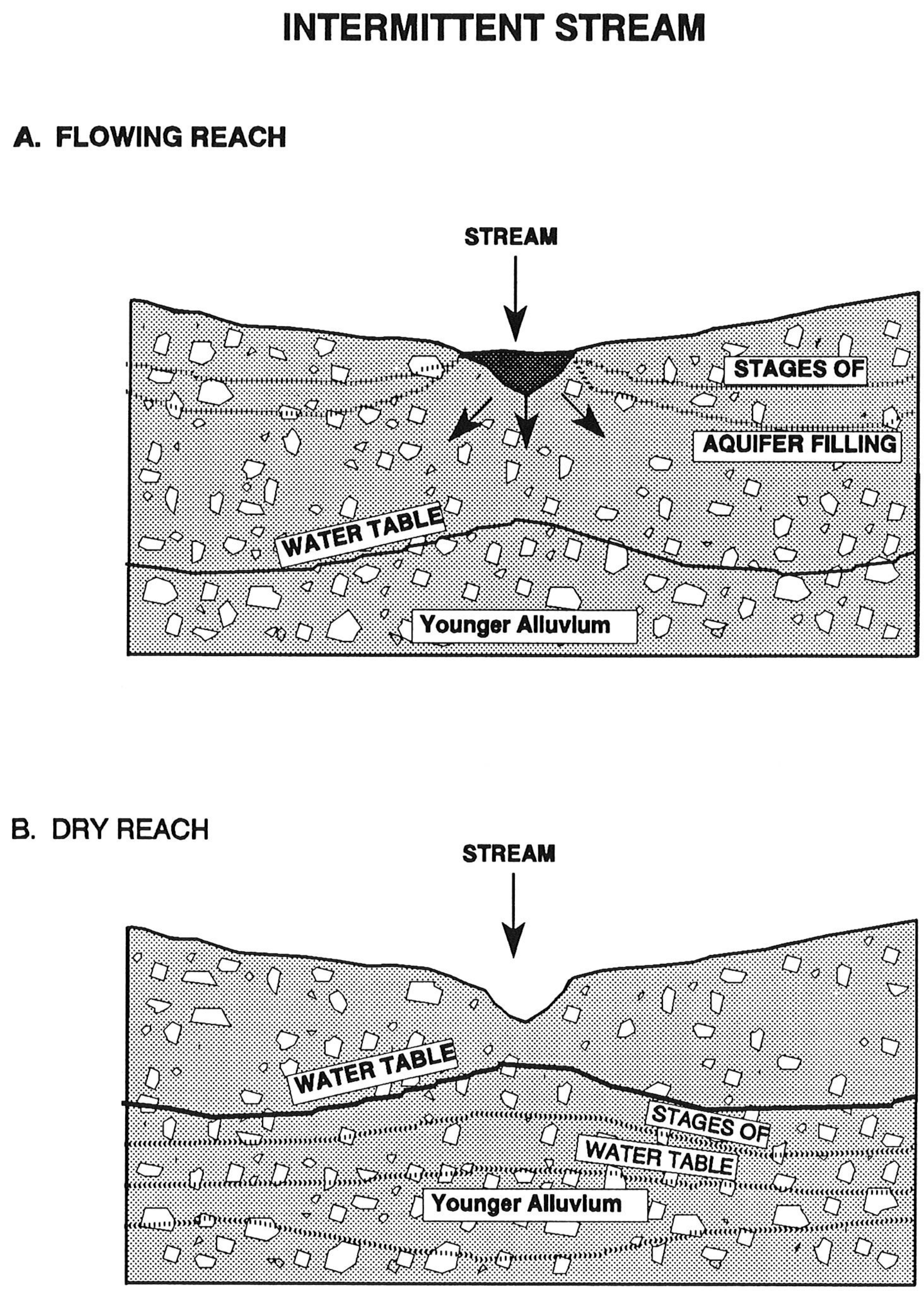

Figure 2-2. Intermittent reaches and their relationship to the water table.

water table lies only a short distance below the streambed. Under these conditions a vigorous habitat of riparian vegetation is often present.

Ephemeral streams discharge water only in response to precipitation events or snowmelt, and do not have a baseflow component at any time of the year; they flow only sporadically. The groundwater system and surface water system do not establish a hydraulic connection in these systems. Therefore, ephemeral streams are always losing streams in relation to the groundwater system.

2.3 AQUIFER TYPES

Aquifers are saturated geologic units that can transmit significant quantities of water under ordinary hydraulic gradients (Freeze and Cherry, 1979). There are three types of aquifers identified in this study: younger alluvium, tributary aquifers, and nontributary aquifers. While these aquifers are distinct hydrogeologic units, they are interrelated parts of the dynamic groundwater system. The distribution of these aquifers in the Gila River system is shown in PLATE 2.

YOUNGER ALLUVIUM

In the Gila River system, younger alluvium aquifers are unconsolidated sand and gravel deposited within the channel course of perennial or intermittent streams by the stream itself (ADWR, 1991). Groundwater in the younger alluvium is derived in large part directly from the stream system. The hydraulic gradients and groundwater flow directions are similar to the associated surface water stream. The groundwater table elevation in the younger alluvium is at or near the surface elevation of the stream.

The younger alluvium is a relatively thin aquifer. In the San Pedro river watershed, the younger alluvium ranges from approximately 10 to 200 feet thick. Also, the younger alluvium occupies only very narrow portions of the alluvial basins within the Gila River system. For example, in the San Pedro River watershed, the younger alluvium is approximately 500 to 7,000 feet wide. The distribution of the younger alluvium in the Gila River system is shown in PLATE 2.

The younger alluvium occurs within, and defines, the channel of perennial and intermittent streams in the Gila River system. It underlies and laterally bounds the associated stream and is a hydrogeologic feature of the stream. The material that comprises the younger alluvium was deposited by the stream in the recent geologic past. For example, as a stream flows across a surface, it scours a channel. The geometry of the channel is governed by the external and internal influences at work on the stream. The external influences include: climate, geology and tectonics, and base level. The internal influences are geographic. As the stream scours the channel, it carries the material scoured from the channel in the flow as bedload. The stream deposits its bedload material in the channel. This material is called alluvium. The texture and thickness of the alluvium is governed by the ability of the stream to move the source material.

Conceptually, the stream builds its channel through scouring and fills it by deposition, thus creating the younger alluvium. Throughout geologic time, river systems have complex scouring and depositional histories as a result of the external and internal forces at work within the system (Schumm, 1981). The river attempts to reach equilibrium with the external and internal influences at work on the system through scouring and deposition processes (Schumm, 1981). These processes proceed at a geologic pace and are continuing today, defining the younger alluvium.

TRIBUTARY AQUIFERS

Tributary aquifers occur between impermeable mountain fronts and younger alluvium. They receive water from mountain front recharge and infiltration from runoff. The aquifers are in direct hydraulic connection with younger alluvium and transmit water to younger alluvium. The tributary aquifers normally have hydraulic gradients distinct from the hydraulic gradient of surface water streams and have flow directions toward surface water streams unless altered by well pumping. The groundwater table elevations of the tributary aquifers are above the surface elevation of the dynamic channel of the surface stream. Typically, tributary aquifers cover large areas and are relatively thick, ranging from 500 to over 2000 feet thick. The tributary aquifers may contain confined zones due to impermeable clay or shale formations within the aquifer.

There are two general types of tributary aquifers: basin fill aquifers and consolidated aquifers. The basin fill tributary aquifers are composed of unconsolidated to semi-consolidated basin fill deposits of sand, gravel and clay zones. These aquifers are common in the large alluvial basins of the central and southern portion of the Gila River system. The consolidated tributary aquifers are composed of consolidated sedimentary and volcanic rocks. These aquifers are common in the northern and eastern portion of the Gila River system. The distribution of tributary aquifers is shown in PLATE 2.

NONTRIBUTARY AQUIFERS

Nontributary aquifers are located in isolated groundwater basins surrounded almost entirely by impermeable hardrock with relatively narrow connections to other groundwater basins and aquifers. Nontributary aquifers have no hydraulic connection with either the younger alluvium or tributary aquifers. Any stream overlying a nontributary aquifer is ephemeral. These aquifers are composed of unconsolidated to consolidated alluvium, sedimentary, or volcanic rocks. The distribution of these aquifers in the Gila River system is also shown in PLATE 2.

AQUIFER FLOW CHARACTERISTICS

Aquifers are more than just reservoirs of groundwater. They are dynamic systems that receive inflows of groundwater, transmit groundwater and, in some cases, discharge groundwater to surface streams (Figure 2-3). The inflow of water recharge occurs from the infiltration along mountain fronts and stream channels, and from infiltration of excess water from cultural uses. Aquifers that border high mountains normally receive significant mountain front recharge and recharge from streamflow infiltration. Aquifers that underlie large areas of agricultural irrigation experience significant recharge incidental to the irrigation practices.

Groundwater in transit will eventually discharge to a stream if not first withdrawn by natural (plant life) or cultural uses (pumpage from wells). The amount of groundwater discharged is equal to the amount of recharge to the aquifer minus the amount of withdrawal. If groundwater withdrawals are greater than recharge, then groundwater discharged from the aquifer gradually decreases. The difference between recharge and withdrawal is supplied from groundwater stored in the aquifer. This situation, known as groundwater overdraft, results in a decline of water table elevations.

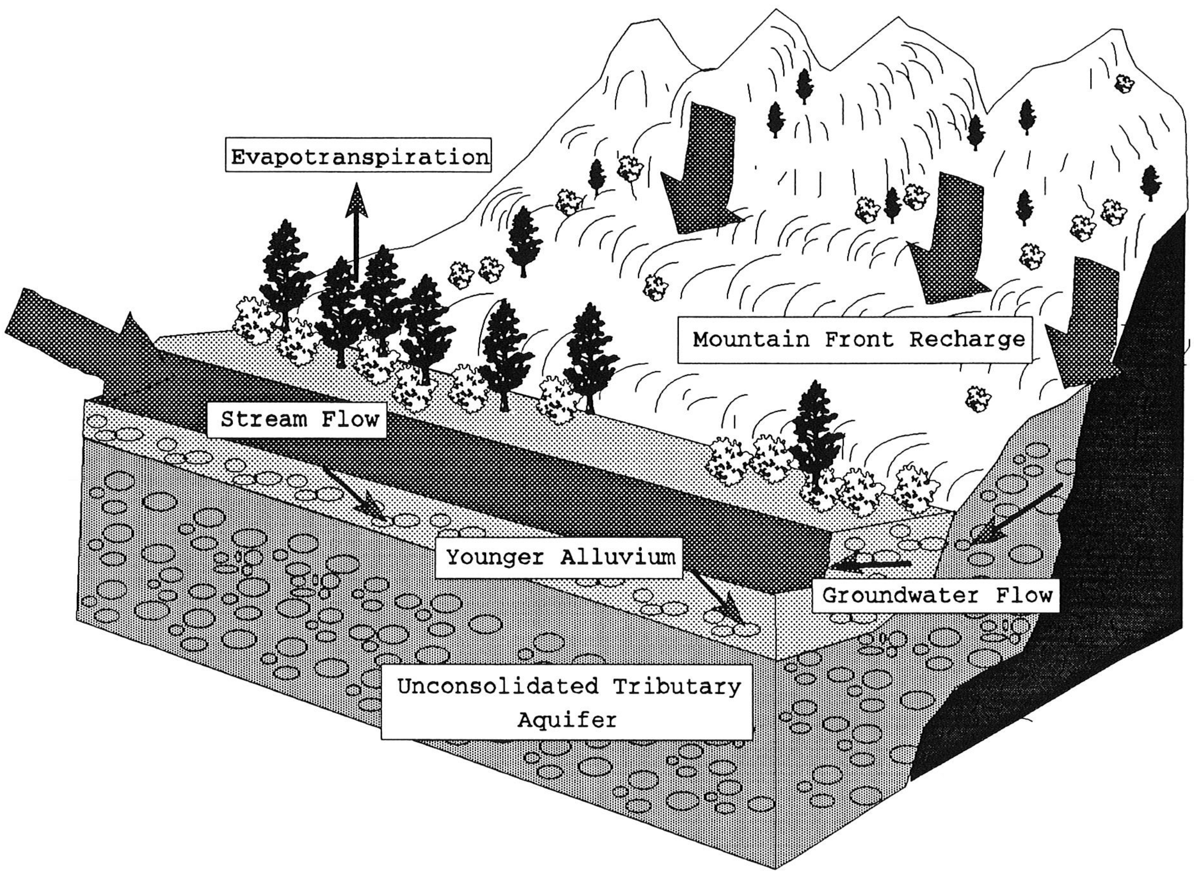

Figure 2-3. Generalized cross-section of aquifers systems.

2.4 GROUNDWATER/SURFACE WATER INTERACTIONS

Groundwater/surface water interactions occur where groundwater is in direct hydraulic connection with a surface water stream. This occurs wherever perennial or intermittent streams are surrounded by younger alluvium. PLATE 3 shows areas of groundwater/surface water interaction in the Gila River system.

There are four types of groundwater/surface water interactions in the Gila River system: alluvial valley streams, alluvial valley streams with confined zones, bedrock canyon streams, and mountain front streams.

ALLUVIAL VALLEY STREAMS

Alluvial valley streams are perennial or intermittent streams that flow in alluvial basins and are underlain and bounded by younger alluvium. The alluvial basin is a structural trough filled with unconsolidated sediments derived from the adjacent mountains. These unconsolidated sediments are generally referred to as basin fill deposits (Anderson, and Johnson, 1985). The perennial or intermittent stream commonly occupies a narrow inner valley, composed of younger alluvium, which includes the dynamic channel of the stream.

A generalized cross-section of an alluvial valley stream segment is shown in Figure 2-4a. As depicted in this figure, the younger alluvium and perennial stream occupy the inner valley. Groundwater in the younger alluvium is in direct hydraulic connection with the stream. The hydraulic gradient and flow direction of the stream and groundwater are the same. Groundwater table elevations in the younger alluvium are similar to the dynamic channel of the stream. The unconsolidated tributary aquifer is in hydraulic connection with the younger alluvium, but the hydraulic gradient and flow direction are not with the stream. The groundwater table elevations in the tributary aquifers are well above the elevation of the dynamic channel of the stream.

The overall groundwater system within alluvial valley stream segments has two broad components: groundwater flowing toward the stream system, and groundwater flowing with the stream system. The groundwater flowing toward the stream occurs in the tributary aquifer. Groundwater in the younger alluvium generally flows in the same

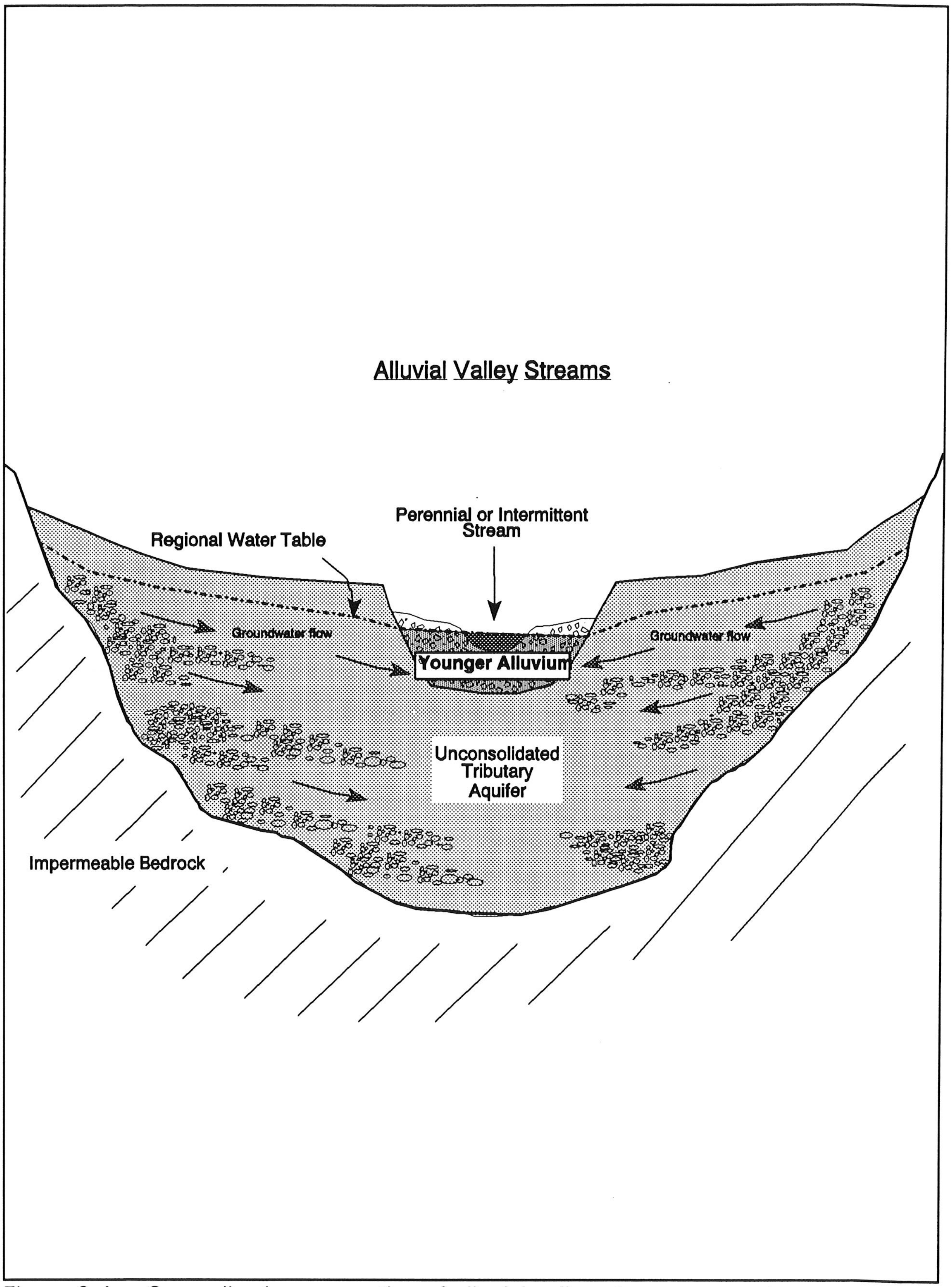

Figure 2-4a. Generalized cross-section of alluvial valley stream segments.

direction as the stream. Groundwater in the younger alluvium is derived predominantly from the overlying stream but, to a lesser degree, also from the adjacent tributary aquifer.

ALLUVIAL VALLEY STREAMS WITH CONFINED ZONES

Alluvial valley stream systems sometimes contain tributary aquifers with underlying confined zones. The confining layers in the tributary aquifer are composed of impermeable silt and clay (Anderson, and Johnson, 1985). The confining layers prevent vertical movement of water from the underlying tributary aquifer to the overlying younger alluvium in particular locations (Figure 2-4b), thus interrupting direct hydraulic connection between the two aquifers. It must be noted, however, that these situations occur only occasionally; whether a particular well withdraws water only from a confined zone should be determined on a well by well basis.

BEDROCK CANYON STREAMS

Bedrock canyon streams are perennial or intermittent streams located in canyons bounded by consolidated tributary aquifers or impermeable bedrock. A typical stream is shown in Figure 2-5. These streams occupy a narrow portion of the canyon floor, underlain and bounded by younger alluvium. The younger alluvium is narrow, surrounded by consolidated tributary aquifers or impermeable bedrock.

Groundwater in the younger alluvium is derived from the surface stream, and flows in the direction of the surface stream. The hydraulic gradient, flow direction, and groundwater table elevation are the same as the stream. Typically, hydraulic connection between the younger alluvium and consolidated tributary aquifers is limited to areas of faults and fractures.

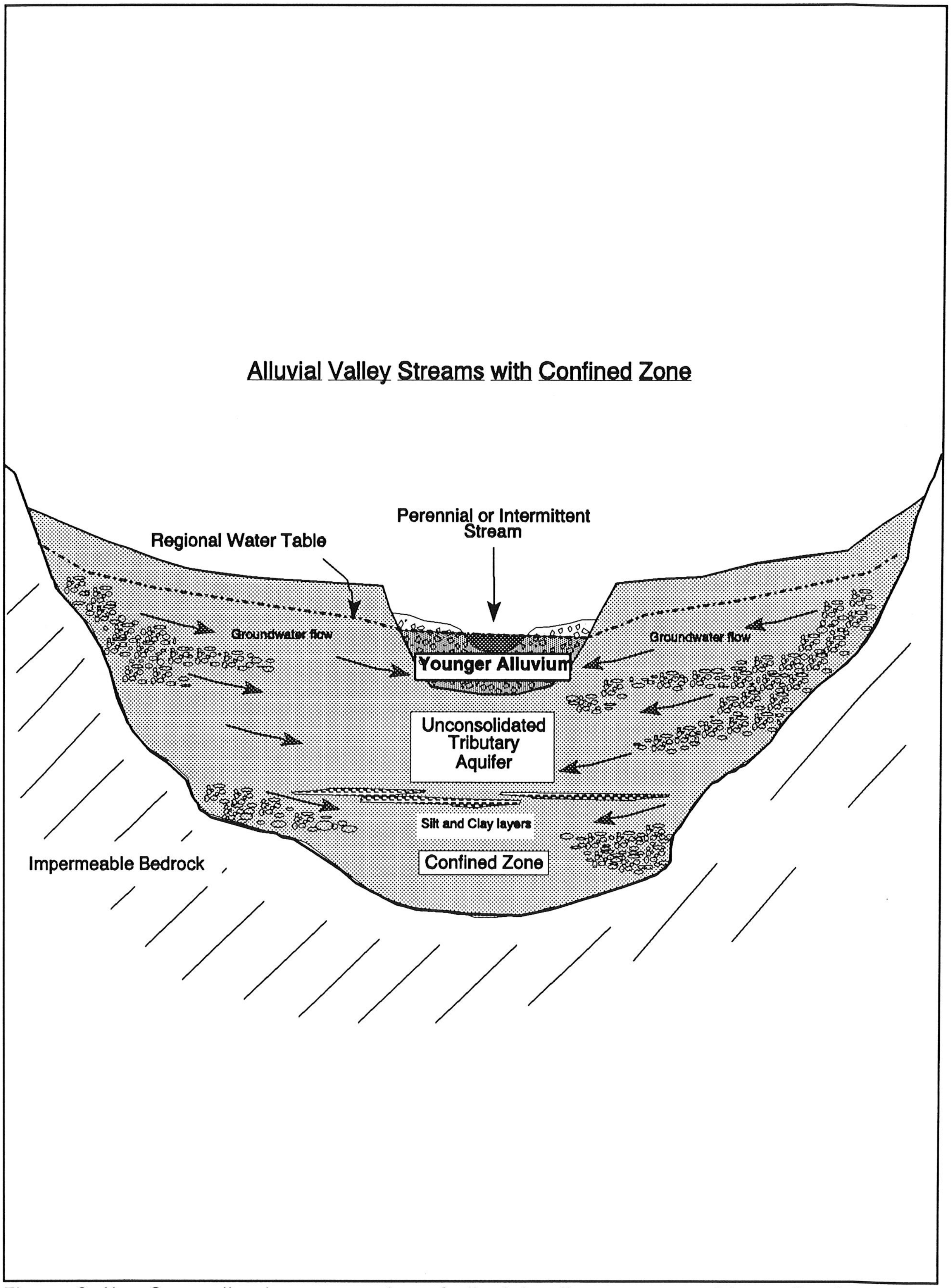

Figure 2-4b. Generalized cross-section of alluvial valley streams with confined zones.

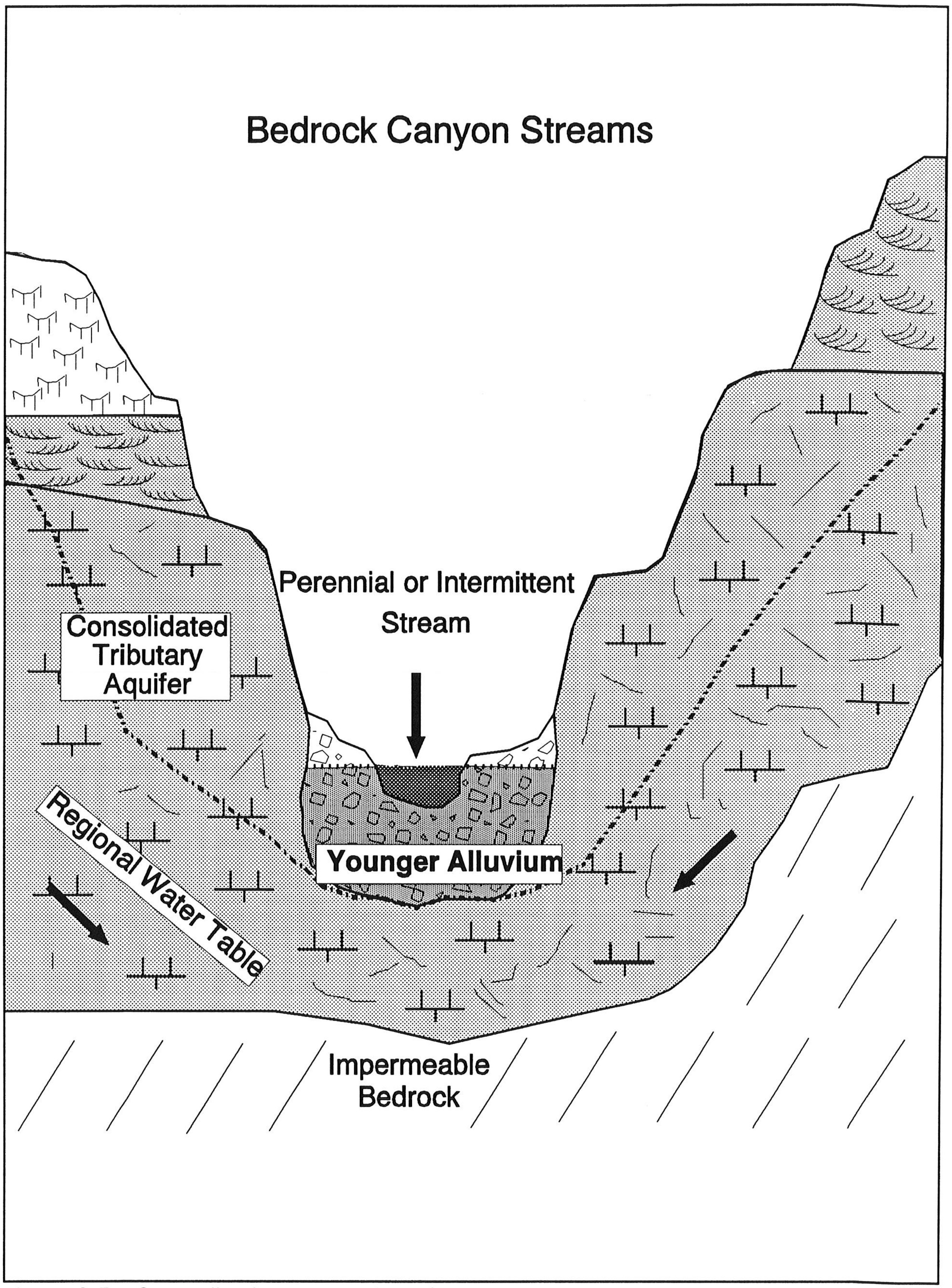

Figure 2-5. Generalized cross-section of bedrock stream segments.

MOUNTAIN FRONT STREAMS

Mountain front streams are stream segments in transition from bedrock canyons to alluvial basins, as illustrated in Figure 2-6. The streams are perennial or intermittent and are underlain and bounded by younger alluvium. Many streams make a transition from bedrock canyon streams, with narrow younger alluvium bounded by hard rock, to alluvial valley streams with younger alluvium bounded by tributary aquifers. The younger alluvium is in hydraulic connection with the stream as it enters the alluvial basin, but the younger alluvium and consequently the overlying stream begin to lose water to the underlying tributary aquifer when the stream enters the alluvial basin. As the stream begins to lose water to infiltration, it transitions from a perennial or intermittent stream to an ephemeral stream. The point at which the river becomes ephemeral is the point at which groundwater/surface water interaction ceases. Subflow becomes nonexistent.

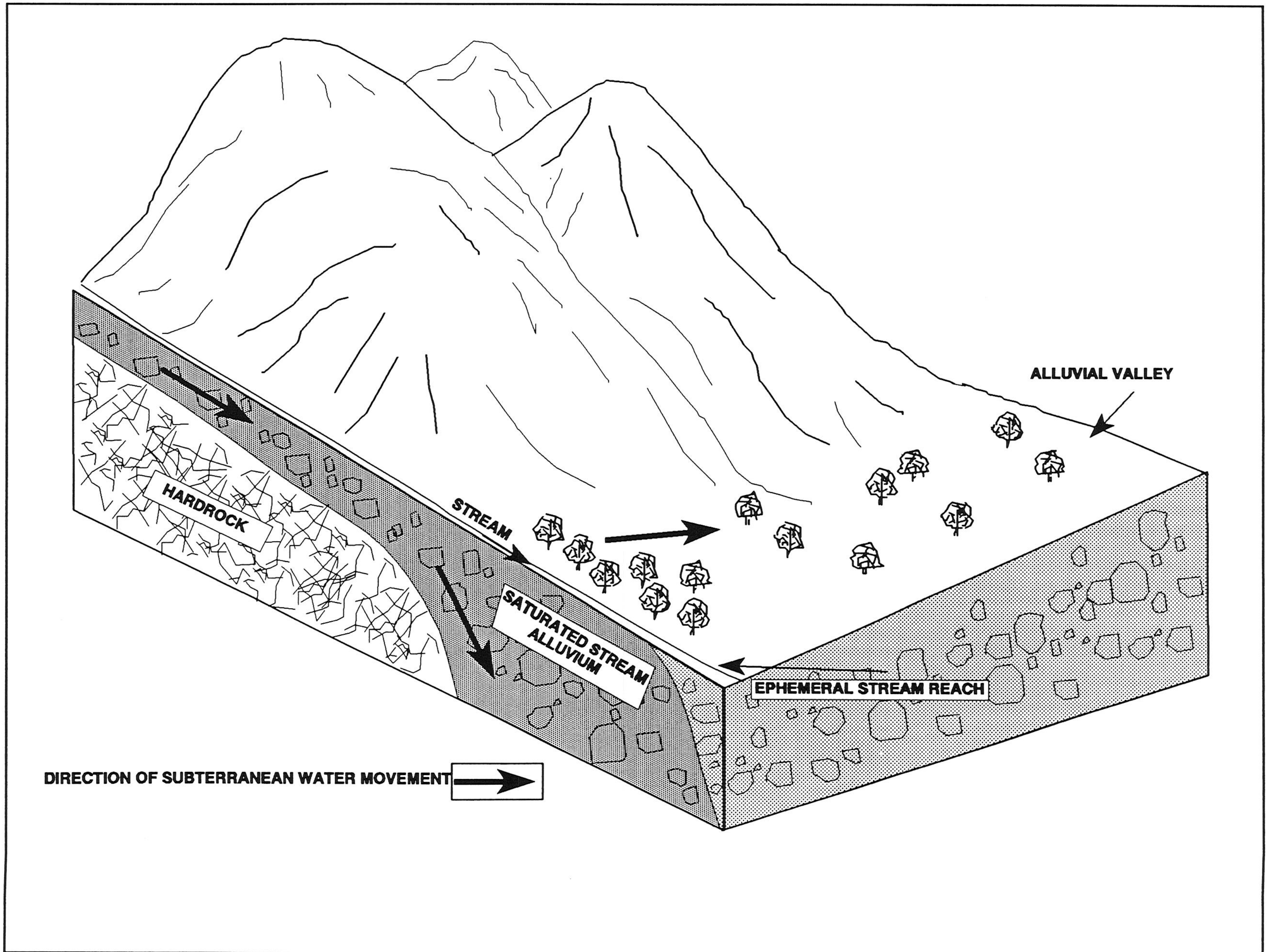

Figure 2-6. Generalized profile of mountain front stream segments.

2.5 GENERAL GROUNDWATER CONCEPTS

The concepts necessary to evaluate groundwater/surface water interaction are summarized by the description of various aquifer and stream types, noted above. To put these concepts in practice, however, a mathematical approach must be devised to accurately predict the flow of water to and from the stream. Without simplifying formulae, the study of groundwater/surface water interaction would be hopelessly stymied by difficult, if not impossible, field measurements of the motion of water concealed beneath the surface of the earth.

This section focuses on three fundamental aspects of predicting the motion of underground water: Darcy's Law, primary groundwater variables, and the analysis of pumped wells.

DARCY'S LAW

The quantitative science of groundwater hydrology lies in the empirical equation derived by Henry Darcy in 1856 (Freeze and Cherry, 1979). Darcy's Law can be expressed as: $Q = -K\,i\,A$

where	Q	=	groundwater discharge (units of volume/time),
	K	=	hydraulic conductivity (units of length/time),
	i	=	hydraulic gradient (units of length/elevation),
	A	=	area in units of length squared.

Darcy's Law expresses groundwater discharge as a function of the aquifer material (hydraulic conductivity), the surface area of the aquifer (area), and the slope of the water table (hydraulic gradient). All quantitative groundwater equations are derivations of Darcy's Law; all include time and volume as the primary factors (Freeze and Cherry, 1979; Bower, 1978; Chow, 1964; and Hubbert, 1940).

PRIMARY GROUNDWATER VARIABLES

Darcy's Law illustrates the primary groundwater variables that influence groundwater movement: hydraulic conductivity, hydraulic gradient, and surface area. Hydraulic conductivity is a function of the aquifer material and fluid, while the hydraulic gradient is a function of change in hydraulic head. Hydraulic head is the height of groundwater above a fixed reference point, typically sea level (Hubbert, 1940). Hubbert showed that groundwater, in simple systems, flows from areas of high hydraulic head to areas of low hydraulic head under the influence of gravity. In other words, the direction of groundwater flow can be determined from groundwater table elevations.

To determine the direction of groundwater flow, the groundwater gradient is determined from groundwater table elevations. Figure 2-7 illustrates the relationship between groundwater table elevation, gradient, and groundwater flow, in three dimensions. The first step in determining groundwater gradient is to draw lines of equal groundwater table elevation (groundwater elevation contours). If the horizontal distance between groundwater elevation contours is 10,000 ft. and the contour interval is 250 ft. then the groundwater gradient is 250/10,000 = 0.025. As shown by Hubbert (1940), the direction of groundwater flow is always perpendicular to the groundwater table elevation contours. The groundwater flow lines in Figure 2-7 show the groundwater flow direction in response to the groundwater gradient. These flow lines thus show only the direction of flow, not the quantity of water moving in any given direction.

Any calculation attempting to quantify the interrelationship between pumped wells, aquifers, and streams will require quantification of aquifer characteristics. The aquifer characteristics derived from hydraulic conductivity are transmissivity and storage coefficient (Hubbert, 1956). Transmissivity is the measure of an aquifer's ability to transmit water from one location to another. It is often expressed in units of ft^2/day. It represents the flow in the aquifer through its entire saturated thickness, but only for a one-foot wide segment. The storage coefficient is a measure of an aquifer's ability to store water within the aquifer material. It represents the volume of water that can be removed from an aquifer by pumping, compared to the volume of the aquifer

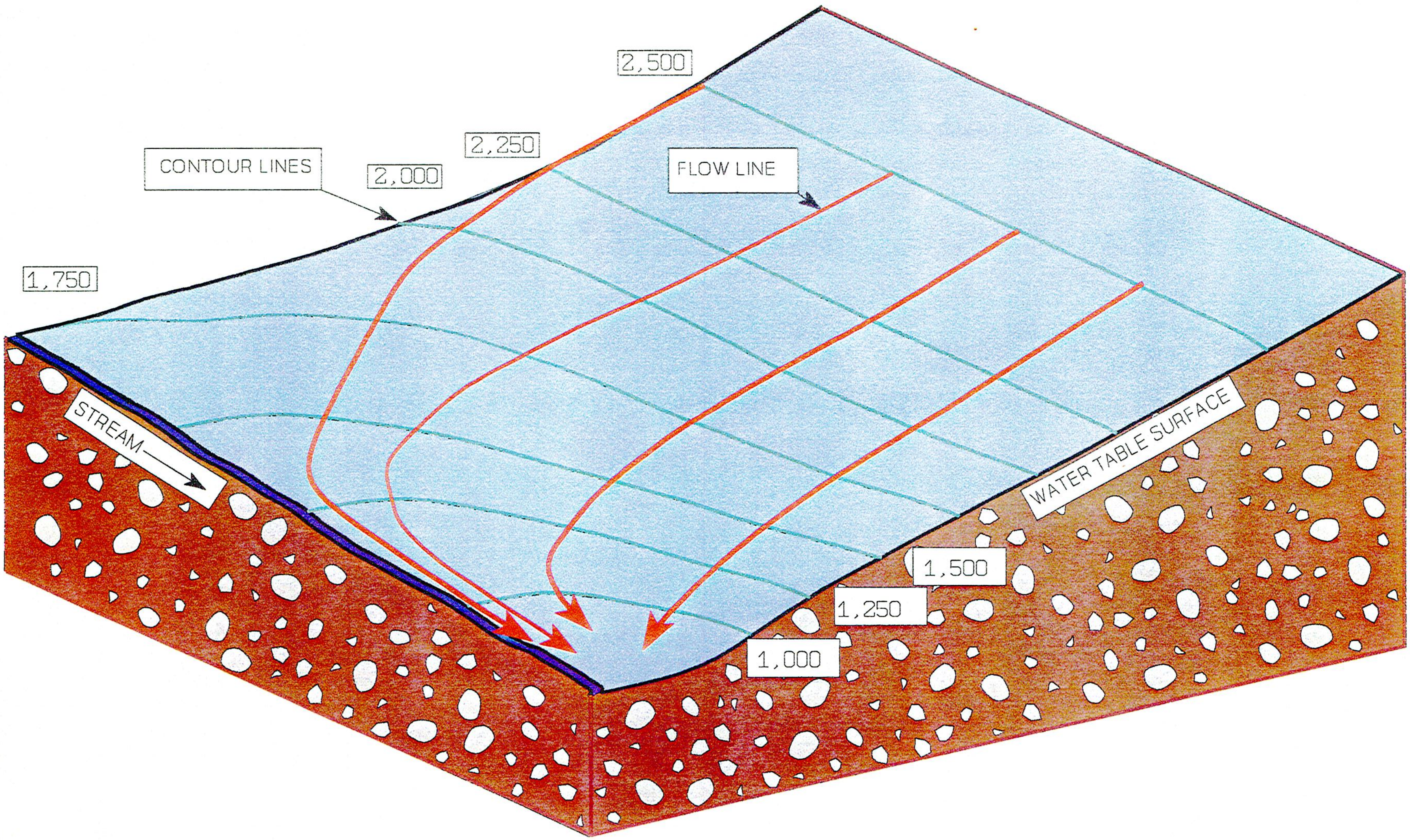

Figure 2-7. Illustration of water table surface, groundwater contours, flow lines and elevation.

itself. For example 10 cubic feet of aquifer material that has a storage coefficient of 0.15 would yield 1.5 cubic feet of water if fully drained by a pumping well.

The value that is assigned to transmissivity and storage coefficient is related to the type of aquifer material. Coarse grained aquifer materials such as sand and gravel have high transmissivity and storage coefficient values. Finer grained alluvium, such as silt and clay, have lower values. Consolidated rock aquifers also tend to have low primary transmissivity values.

PUMPED WELLS

When a well is pumped, water is initially removed from aquifer storage in the vicinity of the well. This creates a cone of depression in the aquifer around the well which, in turn, causes groundwater to move toward the well. The determination of the radius and depth of the cone of depression requires an analysis of time and volume. The cone of depression will vary with the transmissivity and storage coefficient of the aquifer, the pumping rate, and the total time of pumping of the well. If a well is pumped long enough, the cone of depression will expand outward to intercept the recharge or discharge area of the aquifer. There, increased recharge may be induced or the natural discharge may be reduced by the quantity of water necessary to continuously supply the well.

A pumping well may interfere with the stream in one of two ways. Direct interference occurs when a well is located near a stream. The pumping well drains water from the aquifer that is hydraulically connected to the surface stream and flowing with the stream. The pumping well creates a cone of depression that intercepts the streambed and directly induces surface water to enter the well (Figure 2-8a) (Oregon Water Resources Department, internal memorandum, April 24, 1987). Indirect interference occurs when a well is located further from the stream and the cone of depression of the pumped well does not intercept the stream, but the natural hydraulic gradient toward the stream is reduced, thereby reducing the amount of groundwater discharge from the aquifer to the stream (Figure 2-8b).

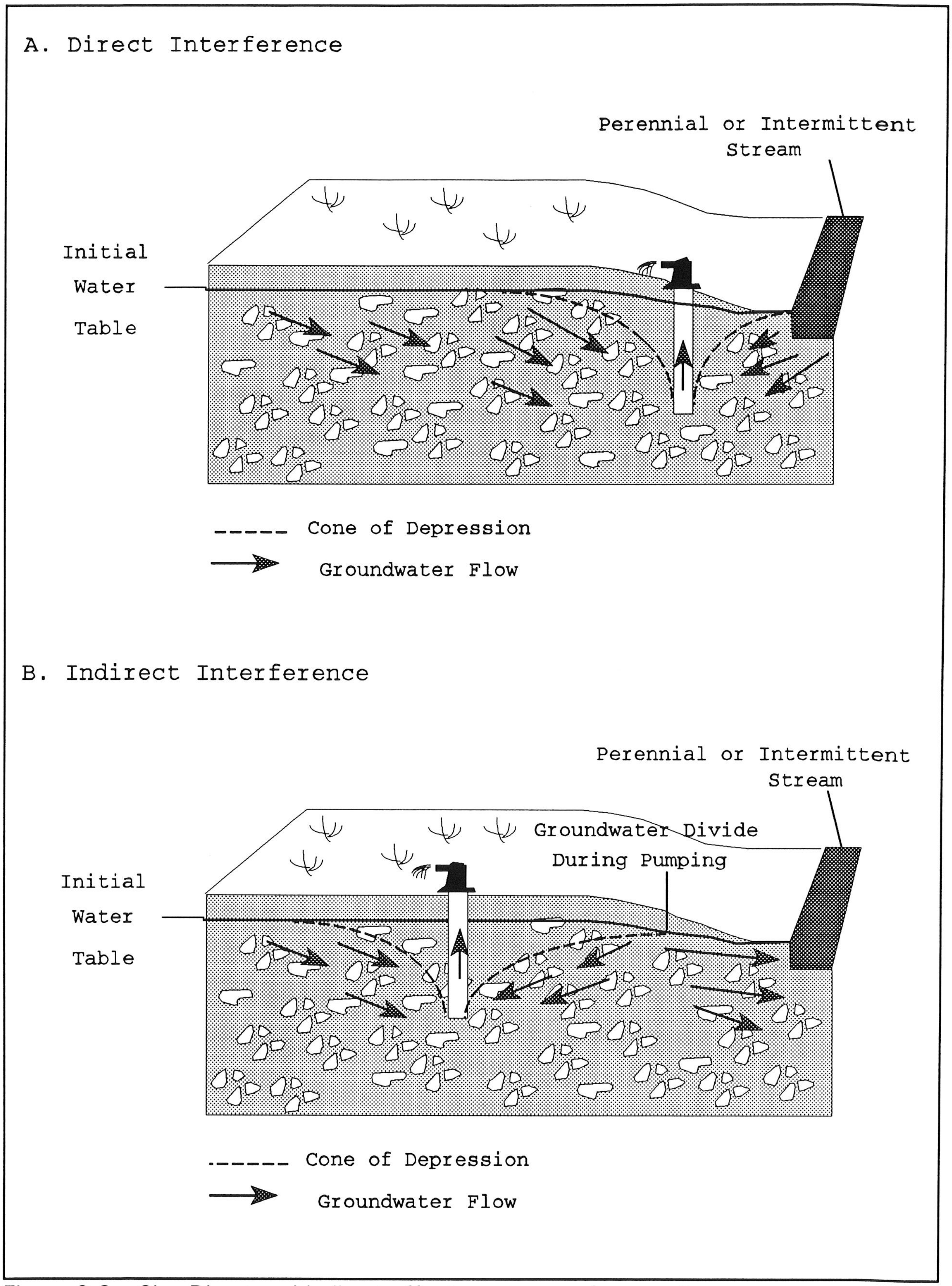

Figure 2-8a, 8b. Direct and indirect effect on streams from well pumpage.

The effects of a pumping well on the stream are often delayed. In cases of indirect interference, the withdrawal reduces the hydraulic gradient of the tributary aquifer to the younger alluvium. It takes a certain amount of time for the gradient to return to equilibrium, notwithstanding the fact that pumping has already ceased. Even for direct interference circumstances, it takes a period of time for the effect of an expanding cone of depression to be felt at the streambed. For certain streams, such as the San Pedro River for example, both direct and indirect interference can occur over the same stream reach. These delayed effects would greatly complicate attempts to regulate well pumpage to achieve a certain rate or volume of streamflow, unless the regulatory formula included a fairly significant factor of time in defining an acceptable amount of depletion.

2.6 PRACTICAL APPLICATION OF GROUNDWATER/SURFACE WATER INTERACTIONS

With the foregoing principles, it is now possible to discuss the methods used to predict the extent of interaction of pumping wells on a nearby stream. There are four general methods available: younger alluvium method, flow net methods, analytical methods, and numerical methods. Each method requires specific data and assumptions to be valid and each has its own limitations. The following discussion is only a general description. A more detailed description is included in APPENDIX A.

YOUNGER ALLUVIUM METHOD

The younger alluvium method takes a general approach and does not attempt to quantify the impact of groundwater withdrawals upon the surface water system. The method is based on identifying aquifers that are hydrogeologically interrelated to a perennial or intermittent stream. Cultural depletions from these aquifers readily impact streamflow. In the alluvial valleys of the Gila River system, as opposed to other watersheds in Arizona, the younger alluvium is such an aquifer.

The younger alluvium was created by the stream during the recent geologic past and water is freely exchanged between the stream and the younger alluvium under natural conditions. These exchanges reflect the gaining and losing reaches of streams that result from seasonal changes in direct surface water runoff. Since the younger alluvium represents the underground support for the stream, cultural withdrawals from the younger alluvium deplete streamflow relatively rapidly. The younger alluvium method is based upon delineating the surface expression of the younger alluvium, a hydrogeologic feature that is readily identifiable on the ground in most locations. It is not based on formulae or methods to calculate the impacts of withdrawals. Within the delineated younger alluvium, withdrawals from wells are expected to have direct and appreciable effect on streamflow.

FLOW NET METHODS

A flow net is composed of lines of equal potential (groundwater contour lines) and groundwater flow lines. The groundwater flow lines represent the path of groundwater flowing in response to gravitational gradient. The area between groundwater flow lines is known as a streamtube. The flow in the streamtube can be calculated from Darcy's Law if hydraulic conductivity is known. A flow net analysis can be used to evaluate the flow direction and discharge in the younger alluvium and tributary aquifer. The flow net will yield the geometry of the groundwater surface which reflects the overall effect of wells on the system, at the instant of observation. However, the flow net method cannot calculate the volume of stream depletion due to a pumping well through time.

ANALYTICAL METHODS

Analytical methods are based upon differential equations derived from Darcy's Law and the Law of Conservation. In order to be valid, analytical methods require that the natural system meet a set of restrictive assumptions. These assumptions are shown in Table 2-1, and are know as Dupuit assumptions.

There are three specific analytical solutions commonly used in groundwater/surface water interaction studies: The Theis solution (1941), the Glover and Balmer solution (1954), and the Jenkins solution (1968). All these methods use the assumptions shown in Table 2-1. Each shows that the depletion of streamflow due to pumping wells is directly proportional to the duration of pumping and aquifer transmissivity. Stream depletion is inversely proportional to the storage coefficient and the squared distance from the well to the stream.

In 1935, C.V. Theis developed a formula to predict drawdown in pumping wells. Six years later he became intrigued by the effect of pumping wells on nearby streams. He adapted his formula to solve the question of how much impact by assuming that the stream and its recharge to the aquifer, induced by the pumping well, could be simulated by an imaginary or "image" well. Using the image well concept, he was able to predict the volume of water withdrawn from the stream by the pumping well and the cone of depression of the pumping well.

TABLE 2-1

DUPUIT ASSUMPTIONS

ASSUMPTION	DEVIATION FROM ASSUMPTIONS MAY CAUSE SIGNIFICANT ERROR	ALTERNATE SOLUTIONS AVAILABLE FOR SMALL VIOLATIONS
Homogenous aquifer	Y	N
Isotropic aquifer	Y	Y
Aquifer of infinite lateral extent	Y	Y
Well fully penetrates aquifer	Y	Y
Aquifer has uniform saturated thickness	Y	Y
Water has constant density and velocity	N	N
Gravity field is uniform	N	N
Flow to the well is radial	N	N
Flow to the well is horizontal	Y	Y
Aquifer is bounded by impermeable beds	Y	Y
Well diameter is zero	N	N
Pumpage from the well is constant with time	Y	Y
Water removed from the aquifer is instantaneously discharged with a decline in head	Y	Y

To conduct image well analysis, Theis first used his 1935 formula to draw the theoretical cone of depression of the pumping well, ignoring its effect on the stream. He then placed the image well on the opposite side of the stream, the same distance from the stream as the pumping well. To simulate recharge from the stream, he drew a cone of depression for the image well the same size and shape as the theoretical cone of depression for the pumping well. The image well cone of depression is drawn upside down to simulate recharge (called a cone of impression). Theis determined the impact of the pumping well on the stream by subtracting the drawdown from the pumping well from the recharge from the image well (Figure 2-9A, B, and C).

The Theis equation applied to streamflow is very cumbersome to solve and uses the Dupuit assumptions. Therefore, Glover and Balmer (1954) simplified the solution to the equation, but with the same assumptions as Theis. Because the solution to both Theis and Glover and Balmer are steeped in higher mathematics, Jenkins (1968) developed a graphical solution. The graphical solution was developed using the same Dupuit assumptions.

Other hydrologists have developed modifications to these equations to solve exceptions to the general case. These modifications include: a limiting outer boundary to the aquifer (Glover, 1960); imperfect connection between the stream and aquifer (Hantush, 1965); bends in the stream (Hantush, 1967); and tributary confluence with the main stream (Glover, 1973). Glover (1973) presents a detailed discussion of the computational aspects of the methods.

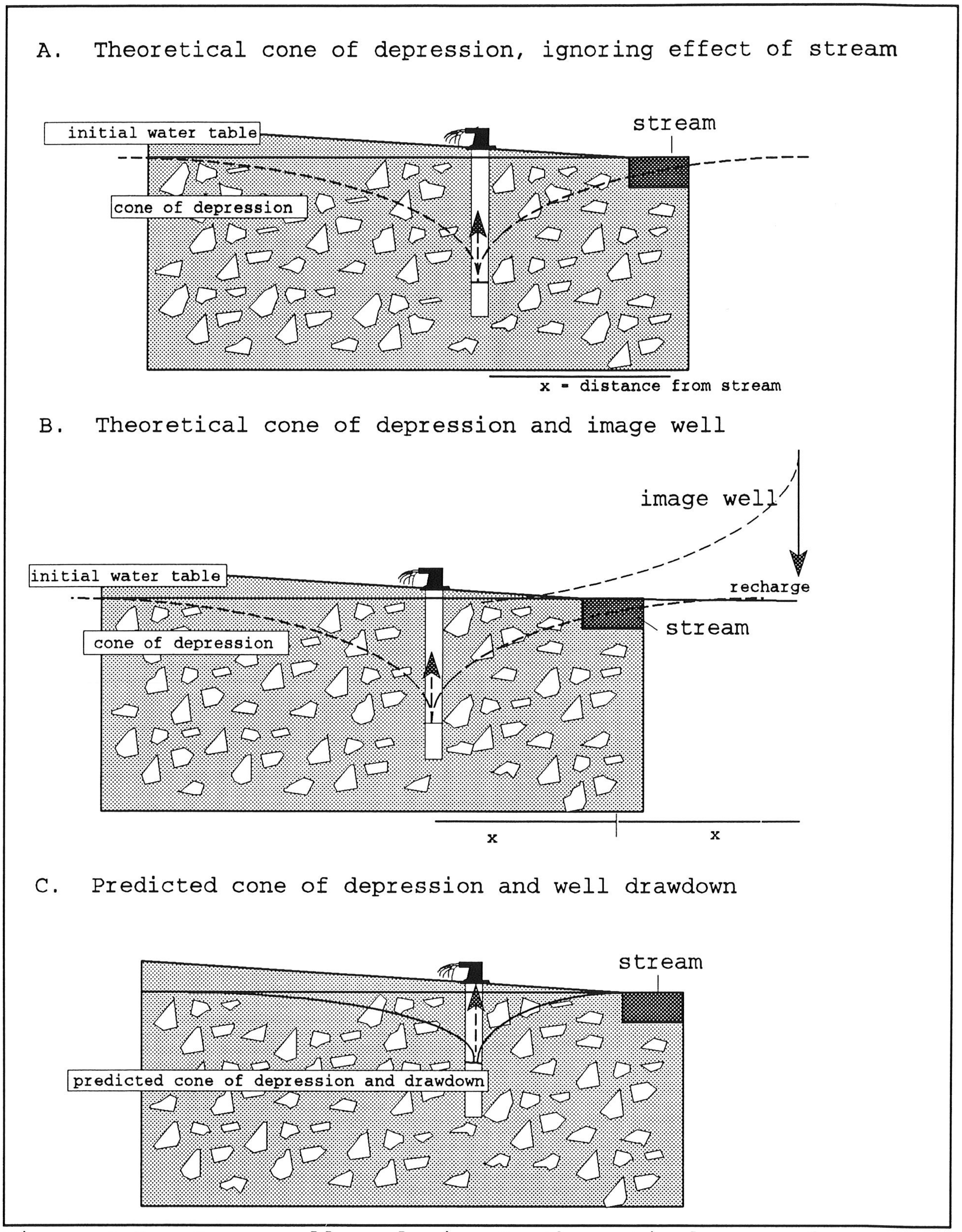

Figure 2-9. Image well analysis: A. theoretical cone of depression from the pumping well, B. image well recharge, superimposed on the pumping well, and C. the predicted cone of depression and drawdown.

NUMERICAL METHODS

Numerical methods are close approximations. Instead of solving differential equations used to describe groundwater flow, the differential equations are transformed into complex algebraic expressions. Digital computers are used to solve thousands of simultaneous equations to solve the algebraic expressions. The solutions are derived through an iterative method that solves the equation at points (nodes) on a grid or mesh which approximates the study area. The iterative method calculates the desired value (usually hydraulic head) at a point by trial and error, simultaneously solving the algebraic expressions for the surrounding nodes. Because of the wide distribution of points across a study area and the algebraic approximation of the differential equations, the number of limiting assumptions is reduced in a numerical solution.

Numerical solutions can use finite element (element area specific) or finite difference (node specific) techniques. Both techniques transform the general equation that describes transient, non-idealized three dimensional flow into an algebraic equation. The equation has the capacity to evaluate recharge and discharge points. The USGS in their ModFlow computer model has the capacity to calculate the effect of streams on the groundwater system (USGS, 1992). However, the river portion of the model has several limiting assumptions.

EVALUATION OF METHODS

Table 2-2 outlines the advantages and disadvantages of the methods discussed above.

The younger alluvium method is based on a hydrogeologic feature defined by aerial photography and in the field, whose definition is not dependent on simplifying assumptions. The method provides a well assessment, but does not provide an estimate of the extent of impact from groundwater uses on the surface water stream.

The flow net method is also a general approach that can solve site specific and regional cases. It is valid for all geologic conditions. The flow nets do not require time/volume calculations and require limited site specific data. However, the flow net analysis is based on static groundwater conditions and may require significant field data collection. The flow net does not provide a solution for the volume of streamflow depleted by well pumping. It is also an instantaneous determination with results that will inevitably change through time.

The analytical methods offer the most precise scientific solutions. However, the solutions are site specific, and may not account for regional effects. They are limited by many assumptions. These solutions do require extensive site specific field data, but do not hold for all geological conditions.

The numerical methods provide regional solutions, but are only as accurate as the available data. Therefore, they require large, high quality data sets. The models generated must be calibrated effectively and can take years to produce. The models do not function acceptably in all geologic conditions.

TABLE 2-2

ADVANTAGES AND DISADVANTAGES OF THE FLOW NET, ANALYTICAL, AND NUMERICAL METHODS

YOUNGER ALLUVIUM METHOD	FLOW NET METHOD	ANALYTICAL METHOD	NUMERICAL METHOD
ADVANTAGES	**ADVANTAGES**	**ADVANTAGES**	**ADVANTAGES**
- can be used to identify individual wells - appropriate watershed wide - no extensive data collection - hydrogeologic feature identified in the field	- can be used to identify individual wells - appropriate watershed wide - requires only groundwater elevation data	- can be used to identify individual wells - numerous solutions - predicts impacts of cultural uses - provides extent of impact - rigorous scientific basis	- reduced assumptions - numerous solutions - predicts impacts of cultural uses - can integrate aquifer recharge and discharge into solution
DISADVANTAGES	**DISADVANTAGES**	**DISADVANTAGES**	**DISADVANTAGES**
- does not determine extent of impact	- does not determine extent of impact - extensive data collection required	- fails in some applications - extensive data collection required - numerous limiting assumptions	- fails in some applications - extensive data collection and verification required

2.7 CONCLUSION

The question of how a pumping well impacts the nearby stream is not a new problem; hydrologists have been examining this problem since the proliferation of high volume irrigation wells in the early 1930s. Over the past 60 years, many qualified researchers have developed sophisticated methods to determine both how the direction of flow is affected by the well and, more importantly, the quantity of that effect. Any one of the methods detailed above could be used to identify wells impacting the surface flow in the watersheds of the state. Each method is based upon established hydrologic theory and years of practice and implementation. Each method, however, contemplates some limiting assumption or arbitrary value within the analysis.

The Arizona Supreme Court, in defining the extent of appropriable subflow within the Arizona system of water rights, has commented on the types of analysis which may be employed to delineate subflow and determine the impact of pumping wells on the stream. The analysis used to delineate subflow and the impact of pumping wells on the stream is dependant upon the interpretation of the Supreme Court's opinion and the reader's resolution of the many conflicting technical provisions within the ruling. The purpose of the next chapter is to analyze the opinion in light of the hydrologic methods that may be employed to delineate subflow and the impact of wells on the stream.

CHAPTER 3: TECHNICAL ASSESSMENT OF THE RECENT ARIZONA SUPREME COURT OPINION ON SUBFLOW

Responsibility for imprecision in the identification of subflow has often been attributed to Arizona's bifurcated system of water law. In DWR's view, however, the difficult problems associated with the identification of subflow arise primarily because the legislature and courts have not specified the necessary arbitrary factors which define its existence. In other states that have a unified water law system, in which both groundwater and surface water are appropriable, there is still a need to establish streamflow interference thresholds for the conjunctive management of groundwater and surface water rights. States such as Colorado and New Mexico recognize that wells located some distance from the stream have an effect. Those states use a time based maximum interference test to identify which wells need to be actively administered in the prior appropriation system. Oregon uses a distance based approach, declaring wells within specified proximity to the stream to be within the law of appropriation. Whether Arizona has a bifurcated or unified system of water law, there still is the need to establish a test for identifying wells which significantly effect streamflow. That test must of necessity incorporate some type of arbitrary factor within its criteria.

The definition of subflow cannot be based simply on an examination of underground hydrology. In the end, the legal parameters established by Arizona statutes and court cases control the issue. Most significantly, the Arizona Supreme Court has recently examined the conflicting positions of the various parties in the Gila River Adjudication over the definition of subflow, and has issued an opinion intended to give the trial court specific guidance on how to define this concept.[2] Any analysis of the distinction between percolating groundwater and subsurface streamflow must recognize the principles stated in the opinion, as they are the law of the State of Arizona.

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[2]*In re the General Adjudication of All Rights to Use Water in the Gila River System and Source*, ___ Ariz. ___, 857 P.2d 1236 (1993).

Some statements in the opinion embody a technical principal or standard that would, in most circumstances, result in narrowing the delineation of subflow compared to the 50%/90 day "brightline" rule set forth in the trial court's order. Other statements seem to require that the brightline be extended beyond the 50%/90 day limit, essentially negating the narrowing guidelines. Virtually any position on the definition of subflow can be supported by using selected phrases within the opinion but, conversely, it is difficult to ascertain any one definition that fits all the technical criteria offered.

The purpose of this chapter is to examine three alternative means for delineating subflow in the context of the various provisions of the opinion, not to advance one particular theory of the Court's intent. The three approaches to be described include: 1) interference tests for determining subflow; 2) geographic tests for determining subflow; and 3) flow net tests for determining subflow. The advantages and disadvantages of each approach will be described along with statements or implications in the opinion that appear to relate to each alternative method.

Before examining the three tests, however, an overview of the state of current law is presented, to place the hydrologic view of subflow into perspective. Then, a prerequisite test for the occurrence of subflow within Arizona is suggested, as an absolutely vital part of any hydrologically based definition. Once the prerequisite test is satisfied, DWR believes that any of the three approaches suggested in this chapter will provide an acceptable basis for the delineation of subflow.

3.1 OVERVIEW

In Arizona, the surface water statutes governing appropriable water only address water flowing in natural channels. See A.R.S. § 45-141. No mention is made of subflow, but in recognition that streamflow can be reduced by pumpage from wells near streams, the concept of subflow developed in case law. The idea was that in some areas there may be a subterranean component of the surface water stream where water is interchangeable between the surface and subterranean parts of the stream. If water is withdrawn from the subterranean component, then a corresponding amount will be lost from the surface component. In the ideal, subflow can be visualized as just another part of the stream that lies out of view below the surface. As part of the stream, it also has distinct bed and banks which define its extent.

This ideal concept of subflow actually does exist in narrow bedrock canyon streams where both the surface and subsurface components of the streams are contained within hardrock boundaries. But as these bedrock canyons descend from the mountains, the valleys become alluvial valleys between mountain ranges, where the subterranean component of streams becomes unbounded. Wells in these larger valleys still can be expected to have an effect on the surface flow, but as the distance between the well and stream increases, the difference between the time when the well is pumped and the time when the effect on the stream is noticed also increases. Likewise, when the distance between the well and the stream increases, the amount of water actually withdrawn from the stream decreases; the balance is made up from the tributary groundwater system.

In these alluvial valley stream environments, the legal dilemma develops. On the one hand, courts have a statutory duty to protect surface water rights against unlawful interference, and it is apparent that the wells are interfering, at least to some extent. But there is also the statutory responsibility to protect the users of the groundwater resource. Wells located at some distance from the stream may have some small effect on water flowing on the surface, but much of the water is coming from tributary aquifers. At some point, the courts must decide how much interference with the stream is acceptable, and how much is not.

The dilemma came to the Arizona Supreme Court when it decided *Maricopa County Municipal Water Conservation District No. One v. Southwest Cotton Co.*, 39 Ariz. 65, 4 P.2d 369 (1931). There, it was apparent that the Court wished to address this problem by establishing subflow as a distinct and limited hydrologic entity; essentially a subterranean water course with discernable bed and banks. The Court described this concept by specifying general criteria which it thought would be sufficient for technical implementation. Instead, it started a decades long tug-of-war between the legal and technical communities on the issue. Arizona's administration of surface water rights has never yet, after 60 years, encompassed the concept of subflow because the guidelines in *Southwest Cotton* were simply too vague.

In its most recent opinion on the definition of subflow, the Arizona Supreme Court again relies on the proposition that subflow is a hydrologic concept which was accepted in 1931, and incorporated into the law of Arizona by the Court when it decided the case of *Southwest Cotton*.[3] In support of this premise, the Court examines the work of Clesson S. Kinney in his treatise, The Law of Irrigation and Water Rights (2d ed. 1912), the same treatise relied upon in the *Southwest Cotton* case. Those portions of Kinney's text quoted by the Court divide underground waters into three classes: 1) Diffused percolation not tributary to any definite surface or underground stream or body of water; 2) percolating waters tributary to surface water; and 3) subterranean water courses. This latter category, subterranean water courses, was further divided into known and unknown courses. Known courses were then subdivided into underground water courses which are independent of a surface stream, and those which are dependent, at least in part, on a surface supply. This final subdivision, according to the Arizona Supreme Court's current analysis, is the area where subflow exists: the known subterranean water course which is dependent upon a surface stream.

The Court makes clear that water in aquifers which are not known underground water courses cannot be classified as subflow. This includes water which has left the known subterranean course and percolated into a nearby aquifer, as well as water in a nearby aquifer which is percolating toward the stream. The Court also makes clear its

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[3]*In re the General Adjudication of All Rights to Use Water in the Gila River System and Source*, ___ Ariz. ___, 857 P.2d 1236 (1993).

belief that these known subterranean courses are not as wide as the entire alluvial valley, reaffirming the principle announced in *Southwest Cotton* that "subflow is found within, or immediately adjacent to, the bed of the surface stream itself." 857 P.2d at 1245. The Court makes frequent reference to the definition of subflow found in *Southwest Cotton*, which described it as follows:

> The underflow, subflow, or undercurrent, as it is variously called, of a surface stream may be defined as those waters which slowly find their way through the sand and gravel constituting the bed of the stream, or the lands under or immediately adjacent to the stream, and are themselves a part of the surface stream.

857 P.2d at 1241, 1245 and Note 9.

In the San Pedro River watershed, like any similar watershed in the Gila River system of perennial or intermittent flow, there is at least seasonal continuity between the groundwater and surface water systems. Water flowing in headwater streams percolates into the regional or tributary aquifer, then flows downgradient toward the watershed drain, which is the main surface water channel. In making its journey through the aquifer, the water takes a deliberate course governed by the gradient of the water table, the transmissivity of the aquifer, and occasional obstructions in the aquifer. As it approaches the stream, the water often enters material of increasing permeability (the younger alluvium). In response to higher transmissivities, the aquifer is able to transmit the same rate of flow with a shallower gradient. In the vicinity of the stream, groundwater levels flatten and the water in the aquifer must either discharge into the surface water stream or turn in the same general direction as the stream. Thus, what originated as surface water high in the mountains became groundwater, then eventually became surface water again, particularly if surface water includes that subsurface flow moving in the younger alluvium, in close proximity to, and in the same general direction as, the surface water stream.

But even where the water enters the younger alluvium or starts to flow in the same general direction as the stream, it is not as though the water passed through a door from one distinct hydrologic entity to another. Aquifers are not homogeneous in their composition. Although the younger alluvium commonly contains material of relatively high transmissivity, it is not uncommon for certain areas of the tributary aquifer to have higher transmissivity than certain areas of the younger alluvium. The water is simply finding its way through an ever changing, but continuous, medium. When it encounters the younger alluvium, it is just another change in transmissivity, although perhaps a relatively large change.

But pumping wells can also change this scenario, further complicating the search for a natural definition of subflow. Instead of the natural condition of water flowing from the younger alluvium into the stream, a reversal of gradient can result from extensive development. Water can be induced to flow from the stream into the younger alluvium or even into the tributary aquifer with sufficiently large and lengthy pumpage. In areas of high development, it is often difficult to tell what the natural predevelopment direction of groundwater flow was. Thus, it is only possible to determine the current condition configuration of aquifer elevations and gradient with certainty.

The law appears to require that in alluvial valley streams, an artificially narrow bed and banks be established for the underground flow so that subflow can be approached as a distinct hydrologic entity. From a hydrologist's viewpoint, however, it is not possible to ascertain a distinct hydrologic entity unless artificial criteria are first established. The technical perspective can tell which wells would derive 100% of their withdrawal from the stream, and which wells would likely withdraw zero percent of their withdrawal from the stream. It can tell what the flow characteristics of the groundwater system are in near proximity to the stream, and what the underground structure of the aquifer probably looks like. If reliable data on aquifer parameters is available, it can even predict the amount of interference that any particular well would have on the stream. But in a continuous hydraulic medium, without the existence of a discrete hydrologic entity to represent the bed and banks of the subterranean stream course, a technical perspective alone cannot answer where subflow exists and where it does not. The definition of subflow must still come from parameters established by the courts or legislature and must necessarily include decisions which later can be characterized as arbitrary or unjustified.

A technical view of subflow in alluvial valley stream situations, then, is not a physical distinction of the hydrologic system, but a certain threshold of interference with the stream. That threshold could be set at 100%. Or, it could be set at 0% encompassing all wells that have even the slightest effect on the stream over the next millennium. Extreme thresholds, of course, either underprotect or overprotect the surface water supply, inducing the decision maker to seek a compromise between these two extremes, such as 25%, or 50%, or 75%. But in selecting any threshold of interference between zero and 100%, the factor of time must be introduced into the criteria before any calculation can be made. Because water pumped from wells can be derived from recharge, aquifer storage, direct streamflow withdrawal, or some combination of these three sources, the amount of water actually derived from each source varies with the length of time considered. In situations where the effects of the pumping well have manifested themselves upon the stream, the longer the well is pumped, the greater the percentage of water is obtained from the stream. Thus, in order to state an absolute percentage, such as 50%, the relevant time period must be specified.

If time is recognized as a necessary factor in determining the impact of the well, two different types of interference thresholds may be attempted. First, the threshold could be established as a brightline test, such as the trial court's 50%/90 day rule, where it was presumed that any well pumping 50% of its volume over a 90 day period would be withdrawing subflow. Of course, the arbitrary limits could be changed to a much more expansive criteria, such as 75% of volume pumped over 100 years, but that would not change the nature of the test. A different method is to establish interference thresholds by the maximum allowable depletion from the stream after a certain duration of pumping, such as one acre-foot of depletion after 10 years of pumping. Again, the arbitrary limits could be changed, but the nature of the test would remain the same. Regardless of the type of test or the arbitrary limits of percentage or volume that are chosen, all interference based tests for subflow must be based upon an arbitrary time period.

There are other methods that establish the extent of subflow which are not based upon volumetric or percentage thresholds of streamflow interference. For example, subflow can be defined as a geographic zone on each side of the stream. Within the zone, it is presumed that wells are capable of significantly reducing streamflow. This can be done by simply specifying a certain distance outward from the stream as the furthest reach of subflow, such as 10 feet, 100 feet, or 1000 feet. Another geographic means with a more technical basis is to define the zone of subflow as the surface of the younger alluvium, which is typically the geologic unit most commonly associated with the stream.

Still another type of test is an instantaneous determination of the zone of subflow based upon the configuration of the aquifer in the vicinity of the stream. This test establishes subflow as that part of the aquifer that has elevations and flow direction more in common with the stream than with the tributary aquifer. All of these methods have advantages and disadvantages. They all must contain arbitrary factors in their criteria; but when the arbitrary factors are supplied, most of the imprecision is removed and the hydrologist can predict which well will be withdrawing water from the stream and, in most instances, how much.

Once it is recognized that the definition of subflow is not a hydrologic reality, but a choice between competing methods of how to best analyze the effect of a pumping well on a stream, the most appropriate method to distinguish wells having an unwanted impact on the stream can be considered. First, however, there should be a prerequisite test for hydraulic connection between the aquifer and the stream, to eliminate wells which cannot, under modern circumstances, affect the surface flow.

3.2 REQUIREMENT OF HYDRAULIC CONNECTION

In the early twentieth century, before widespread use of pumping wells began, streams with active groundwater/surface water interactions were common in the Gila River system, even in the lower desert valleys. After many decades of pumping, a significant number of these groundwater/surface water interconnections have been severed, and the streams in these locations have transitioned from perennial flow, with associated riparian habitat, to ephemeral desert washes. It needs to be recognized, however, that over these years groundwater that once was associated with these streams has supplied many diverse water uses that could not have been supplied by surface water alone. In most of these situations the amount of surface water lost by severing the groundwater/surface water interconnection has been far less than the amount of water supplied from the groundwater resource.

On streams where the groundwater/surface water connection has been lost, it would not be practical or feasible to try to reestablish the connection because it would require that a very large amount of water be restored to the groundwater system in order to regain a relatively small surface water supply. For these reasons, DWR suggests that the issue of determining the location of subflow in the general adjudication be limited to those stream reaches where groundwater/surface water interconnections currently exist. If this limitation is accepted by the Court, then the initial step in any criteria adopted to delineate the location of subflow is to determine the stream reaches where streamflow interference from pumping wells can physically occur.

DWR suggests that two qualifying inquiries be made as a prerequisite test to determine whether subflow can physically occur in the stream reach in question: 1) perennial or intermittent streamflow conditions must occur in the stream reach; and 2) the underground aquifer must at least seasonally establish hydraulic continuity with the surface water stream. Unless these two conditions occur, pumpage from wells adjacent to the stream will have no measurable effect on reducing the amount of water flowing in the stream.

Furthermore, this prerequisite test can only be carried out using current data on streamflow and groundwater level conditions. Although hydraulic continuity occurred in many areas of the Gila River system under predevelopment conditions, it is not possible to recreate these predevelopment conditions for analysis. Therefore, only areas where active groundwater/surface water interactions currently occur should be examined for potential subflow.

If this prerequisite test is satisfied, the final definition of subflow rests upon which type of test the courts choose to define the zone of appropriable subflow.

3.3 INTERFERENCE TESTS FOR DETERMINING SUBFLOW

If a well near a stream is pumping water from an aquifer in direct hydraulic connection with the stream, it may be assumed that the well is depleting the surface flow by some measurable amount. As noted in Chapter 2 of this report, several hydrologists have devoted considerable effort in perfecting mathematical approaches to determine exactly how much water is being depleted. While all of these approaches rely on certain fundamental assumptions to simplify the problem and make it workable, application of the methods with sufficient data can produce reliable predictions of the impact of pumping wells on the stream. The greatest uncertainty is the necessary arbitrary limits upon which to draw the ultimate conclusion: is the amount of interference acceptable?

There are two basic ways to apply interference tests. One is to derive a "brightline" distance from the stream where wells are calculated to have a certain percentage of impact. The second type of interference test determines actual impacts of individual wells. The impact calculated from each well can then be compared against an acceptable threshold of interference, such as no more than one acre-foot per year of stream depletion after 10 years of continuous pumpage.

In the 1987-88 proceedings in this case, the trial court adopted a standard where any well predicted to extract 50% of its total volume after 90 days of continuous pumpage would be subject to the jurisdiction of the Court. The Arizona Supreme Court, it its recent opinion, commented on this approach, as follows:

> Likewise, the 50%/90 day "volume-time" test does not find its origin in *Southwest Cotton*. Given enough time, and with certain exceptions, all extractions from a tributary aquifer will cause a more-or-less corresponding depletion from streamflow volume. That, indeed, is the basis of the continuing controversy between groundwater pumpers and surface appropriators. *Southwest Cotton*, however, did not purport to identify subflow in terms of an acceptable amount of stream depletion in a given period of time. It sought to identify subflow in terms of whether the water at issue was part of the stream or was percolating water on its way to or from the stream.

857 P.2d at 1245-46.

On the other hand, the Supreme Court did not totally disapprove the volumetric analysis of pumping wells on the stream. Immediately preceding the above quoted paragraph, the Court stated:

> Thus, if a well is drawing water from the bed of a stream, or from the area immediately adjacent to a stream, and that water is more closely related to the stream than to the surrounding alluvium, as determined by appropriate criteria, the well is directly depleting the stream. If the extent of depletion is measurable, it is appreciable. This is not an all-or-nothing proposition. For example, if the cone of depression of a well has expanded to the point that it intercepts a stream bed, it almost certainly will be pumping subflow . . . . Even though only a part of its production may be appropriable water, that well should be included in the general adjudication.

Id. at 1245 (footnote omitted).

In DWR's opinion, the only way to predict whether the cone of depression in this scenario will intercept the stream is to mathematically simulate pumpage from the well over a specific period of time. Those mathematical simulations can only be performed using one of the analytical or numeric modeling techniques described in Chapter 2. The practical considerations regarding accurate data for these parameters and representative aquifer conditions between the well and stream have been extensively described in the 1987 groundwater hearing and reports, and in the Hydrographic Survey Reports (HSR). In DWR's opinion, the time-based interference analytical methods provide the most substantial scientific means to assess the impact of wells on the stream and are the most frequently cited means in the literature and in other states' procedures.

The advantages of the analytical interference test are its rigorous scientific basis, and its ability to predict impacts from individual wells. Its disadvantages are its extensive data requirements and the sensitivity of the results to the amount and accuracy of the data. It also requires the specification of arbitrary time/volume or time/depletion factors.

A revised interference test could be readily implemented by DWR for both the San Pedro and Upper Salt River watersheds since the necessary aquifer data has already been collected and analyzed in support of the 50%/90 day test that was performed in those two watershed HSRs. If an interference test threshold for individual wells was adopted (certain maximum rate of annual depletion after a certain number of years of pumping), then the analysis could be performed assuming that the quantity pumped is based upon the quantification of the potential water right in the HSR or the quantity assigned to the right by the Special Master. In either event, it would not require an extensive resource investment by DWR to carry out this type of test within these two watersheds. In future watersheds, however, DWR would require an investment equivalent to that expended in the two current HSR watersheds to collect and analyze the necessary data. DWR estimates that a revised interference test could be implemented for the San Pedro River HSR within 4 months of a final determination of the Court.

3.4 GEOGRAPHIC TESTS FOR DETERMINING SUBFLOW

Geographic tests for determining subflow are not based upon a mathematical calculation of streamflow interference. Instead, they are based on a presumption of interference within a certain geographical distance from the stream. The distance outward can be set by a single criterion applicable to all stream reaches, or the distance can be set incorporating a technical factor on a reach-by-reach basis.

UNIFORM DISTANCE

This method has been used in other states' general adjudications and by other states' water administration agency. These states, however, either have a unified water code or have riparian law provisions. Some examples are listed below.

Scott River adjudication, California "Claimants listed in Schedule C are allotted that amount of water, by subirrigation or by pumping from ground water interconnected with the Scott River, reasonably required to irrigate the acreage shown opposite their names. [A]dditional wells or sumps may be constructed to augment irrigation or to replace subirrigation but must be located at least 500 feet from the Scott River . . . ." (emphasis added).

Oregon

The Oregon Water Resources Department (OWRD) has developed administrative rules which established criteria for the determination of groundwater interference with surface water (OWRD Administrative Rules - Chapter 690, Division 9). The following describes the salient criteria to be used by the OWRD

1. Determine whether wells produce water from a confined or unconfined aquifer.
2. Determine if the aquifer is hydraulically connected to the surface water source.
3. All wells located a horizontal distance of less than one-fourth of a mile from a surface water source that produce water from an unconfined aquifer shall be assumed to be hydraulically connected to the surface water source.

4. All wells that produce water from an aquifer that is determined to be hydraulically connected to a surface water source shall be assumed to have the potential to cause substantial interference with the surface water source, if:
   A. the point of appropriation is a horizontal distance less than one-fourth mile from the surface water source; or
   B. the rate of appropriation is greater than 5 cubic feet per second, if the point of appropriation is a horizontal distance less than one mile from the surface water source; or
   C. the rate of appropriation is greater than one percent of the pertinent adopted minimum perennial streamflow or instream water right with a senior priority, or of a discharge that is equalled or exceeded 80 percent of the time, and if the point of diversion is a horizontal distance less than one mile from the surface water source; or
   D. the groundwater appropriation, if continued for a period of 30 days, would result in stream depletion greater than 25% of the rate of appropriation, if the point of diversion is a horizontal distance less than one mile from the surface water source.
5. All wells that produce water from an aquifer that is not hydraulically connected to a surface water source shall be assumed not to interfere with the surface water source.

In Arizona, of course, there has been little discussion of uniform distances for the definition of subflow, perhaps for two reasons. First, there is the *Southwest Cotton* legacy of a known subterranean water course which militates against a simple surface measurement for the subterranean flow. Second, the selection of an appropriate distance is seen as a completely arbitrary product of judicial fiat. Thus, the matter was not even discussed by the Arizona Supreme Court in its discussion of subflow, and would likely draw considerable protest if adopted now.

Nevertheless, when viewed objectively, the uniform distance approach has much to commend it. It is easily understood and easily administered. If the stream reach in question is studied carefully before adoption of a specific distance, the unwanted interference of wells can be kept to a minimum. The disadvantage is that wells just outside the arbitrary zone of appropriability can continue, or even proliferate, without regard to any incidental surface water interference.

YOUNGER ALLUVIUM

In the alluvial valley streams of the Gila River system, the closest hydrologic equivalent to the known subterranean water course is the geologic feature of the younger alluvium. Typically, a hydrologist seeking to examine the effect of pumping wells on a stream in these environments will begin the analysis with the examination of wells inside the younger alluvium. Thus, it is not surprising that the trial court also applied the 50%/90 day test to all wells found to be located within the younger alluvium; it is a natural point of minimum beginning for the subflow analysis.

The Arizona Supreme Court commented on the trial court's use of the younger alluvium in its opinion, stating:

> The record shows, however, that in a given area the younger alluvium may stretch from ridge line to ridge line so that all wells in the valley would be in or near the younger alluvium. To say that all of an alluvial valley's wells may be pumping subflow is at odds with *Southwest Cotton's* statement that subflow is found within or immediately adjacent to the stream bed.

857 P.2d at 1245. Likewise, the Court reiterated:

> We believe the trial court's 50%/90 day rule expands the clear words of A.R.S. § 45-141(A) to include not only waters flowing in streams but, potentially, water pumped any place in the younger alluvium.

Id. at 1247. These statements, however, can be analyzed on two separate theories.

First, the record in the trial court is misleading to the extent that it shows that younger alluvium can stretch from ridge line to ridge line. This is an extremely rare occurrence in Arizona and on those few occasions where it does occur, the valley is usually bounded by confining strata, making the subterranean water course and the surface stream practically one in the same. The alluvial valley, on the other hand, stretches from ridge line to ridge line by definition. This may have been what the Court had in mind, as it seems to use the terms interchangeably (see first quotation, above).

Secondly, a younger alluvium test would not automatically conclude that all wells in the younger alluvium would be withdrawing subflow. As noted above, a prerequisite to the occurrence of subflow is that there must be at least a periodic hydraulic connection between surface water and groundwater systems. Without this connection, the rate of infiltration through the bed and banks of a stream is not affected by pumping wells, and therefore they have no measurable impact on the surface flow.

Where there is a hydraulic connection between the water in the younger alluvium and the water in the stream, it is a reasonable technical premise that wells withdrawing water from the younger alluvium are having some impact on the surface flow. As the Supreme Court noted:

> As we stated above, it turns on whether the well is pumping water that is more closely associated with the stream than with the surrounding alluvium. For example, comparison of such characteristics as elevation, gradient, and perhaps chemical makeup can be made. Flow direction can be an indicator. If the water flows in the same general direction as the stream, it is more likely related to the stream.

Id. at 1246.

Here the Court seems to imply that the younger alluvium would be an appropriate test for subflow because the younger alluvium is, in fact, where underground water becomes more closely related to the stream than to the adjacent tributary aquifer in terms of elevation, gradient, and flow direction. Most hydrologists would consider whether a well is located in the younger alluvium to be at least a usual first step in assessing possible interference with the stream.

The advantages of the younger alluvium test are that it can be readily delineated with reliability in most locations using stereoscopic aerial photography and field verification. It does not depend upon the collection of a large amount of aquifer parameter data to be applied accurately, and its delineation is not dependent upon the effects of past or future development on aquifer gradients and elevations. It is based upon observed rather than calculated factors, thereby providing a method of considerable certainty. Its disadvantages include the fact that it extends hundreds to thousands of feet outward from the stream in some locations.

The younger alluvium has been defined and mapped by DWR in the San Pedro and Upper Salt River watersheds. Maps of the younger alluvium have already been generated as part of the Zone 1 analysis for these watersheds and as such are available for immediate implementation of the test. Therefore, no additional costs to DWR or the adjudication process would be necessary to implement this test. DWR believes that the San Pedro River HSR could be revised to this standard 3 months after a decision by the Court. Since the HSRs for these two watersheds contains an extensive explanation of the methodology and presentation of results, the steps involved in implementing this test are not repeated in this report. The interested reader is referred to either the San Pedro or Upper Salt River HSRs for a detailed explanation.

It is DWR's conclusion that a line drawn along those portions of the younger alluvium in direct hydraulic connection with a perennial or intermittent stream is an effective, well reasoned approach to the definition of subflow geography. The younger alluvium, in DWR's opinion, is the hydrogeologic feature which most closely represents the subterranean water course of alluvial valley streams. It is a geologic unit of mostly sand and gravel that was deposited by the stream itself in recent geologic time, and as such, it is more closely associated with the stream history than to the history of the tributary aquifer.

3.5 FLOW NET METHODS FOR DETERMINING SUBFLOW

The foregoing sections of this chapter have described two recognized tests to distinguish percolating groundwater from appropriable subflow: 1) time/volume thresholds based on percentage of withdrawal or volumetric depletion; and 2) geographic appropriability zones based on the younger alluvium or distance from the stream. Despite their unique individual advantages, each has the similar disadvantage of running contrary to some particular expression within the Arizona Supreme Court opinion. Arguably, the Supreme Court was looking for a new test which would not involve either time or the younger alluvium as a relevant standard.

In attempting to find a new test for appropriability, DWR concluded that two central themes appear to run throughout the Court's opinion. First, the Court suggests that subflow should be found relatively "close" to the stream or, in other words, that subflow is a narrow concept. Secondly, the Court emphasizes that subflow of the stream should move in the same general direction as the stream. In typical alluvial valley streams, however, there is no natural boundary which fits this description, aside from perhaps the younger alluvium. Therefore, DWR looked to methods based upon elevations, gradients, and flow directions of the groundwater table to predict on the land surface where the underground water turns and begins to flow more in the direction of the stream rather than to or from it.

By delineating the configuration of the groundwater table, it is possible to create a geographic appropriability zone within which a well would be presumed to be withdrawing subflow. The basic model is an adaptation of a standard hydrological technique called a flow net. DWR has modified the technique, however, to suit the needs of this inquiry. Thus, the label "modified flow net analysis" will be used throughout this report to describe this unique application.

The modified flow net analysis provides an instantaneous determination of the direction of underground water based upon groundwater elevations and gradients. The test relies on actual groundwater elevation data measured from wells. As a result, the accuracy of the test is dependent upon the number of wells measured and the accuracy of the measurements. Furthermore, if wells are measured immediately before the model is prepared, the resulting flow net will simulate the most up to date conditions in the aquifer.

The modified flow net analysis is a geometric solution which defines a discrete underground hydrologic unit where water is moving more with the stream than to or from it. The test does not determine the extent of impact of uses on the surface water stream. In this regard, it fits well with the Supreme Court's interpretation of *Southwest Cotton:*

> *Southwest Cotton*, however, did not purport to identify subflow in terms of an acceptable amount of stream depletion in a given period of time. It sought to identify subflow in terms of whether the water at issue was part of the stream or was percolating water on its way to or from the stream.

857 P.2d at 1245-46.

The advantages of the modified flow net method are that it defines an area of the subterranean water course that is more closely related to the stream than to the surrounding tributary aquifer. This requirement appears to be the central test in the Supreme Court's opinion, and appears to be the least controverted by other guidelines in the opinion. Its disadvantages are that the boundaries of subflow established by this test are highly influenced by the effects of past well development in the area and, if periodically reviewed, will continue to change over time as pumpage continues. In some areas the effects of past pumpage cause the boundaries of subflow determined from this test to extend more than a mile outward from the stream, even extending past the younger alluvium.

DWR believes it would need to measure as many wells as possible within reasonable proximity to the stream to carry out this test. Furthermore, these measurements would need to be made during a time of year that would reflect the best determination of static water levels. DWR estimates that it would require approximately 12 to 20 months from the time of the final order to implement this test for the San Pedro and Upper Salt River watersheds depending upon the time of year that the order is extended.

Because the modified flow net analysis is a completely new approach to the definition of subflow, it will receive a much more detailed explanation in the following chapters of this report. Through the preparation of this test, DWR believes that it has created a method which meets the prescription of the Supreme Court even under the strictest of interpretations.

CHAPTER 4: PROPOSED CRITERIA

The purpose of this chapter is to define geographic areas of appropriable subflow using only the least controversial legal parameters of the Court's opinion, as discussed in Chapter 3. The method proposed within this chapter is unlike other hydrologic methods in that it is an instantaneous determination. It is a modification of the flow net analysis described in Chapter 2, and is hereafter referred to as the modified flow net analysis. The modified flow net analysis uses only the geometry of the subterranean water surface in relation to the surface stream elevation to determine flow direction. It does not consider volume of flow or changes in the geometry which inevitably occur with the passage of time.

This chapter describes the proposed method in general terms. A more detailed explanation may be found in APPENDIX B.

4.1 PROPOSED CLASSIFICATION OF WELLS

As stated in Chapter 3, the Arizona Supreme Court has suggested several requirements for determining the correct geographic locations of subflow. The Court notes that the direction of flow can be an indicator of the geographic boundary defining subflow as well as the elevation of the subterranean waters. The Court also notes that the determination must define water which is more closely related to the stream than to the surrounding aquifers. Utilizing these legal parameters as the primary directives from the Court, DWR developed the modified flow net method around the following assumptions.

1. For subflow to exist, there must be a hydraulic connection between the stream and the subterranean waters. The stream must be either intermittent or perennial and the subterranean waters must be at the same general elevation as the stream.

2. The subterranean waters need to flow in the same general direction as the stream and should have the same chemical makeup as the stream.
3. Time should not be a consideration in the technical determination of subflow areas.
4. All wells located within the delineated areas will be considered to be pumping subflow unless further proof is provided by the well owner(s).

DWR has utilized the baseline conclusions above to develop three necessary procedures for determining the geographic extent of the subflow areas. The basic steps of the model are outlined below. They are discussed in further detail in this chapter and in APPENDIX B.

1. Determine areas where subflow may exist.
    a. Determine that the stream is perennial or intermittent.
    b. Determine that a hydraulic connection exists between the subterranean water and the stream. The existence of saturated younger alluvium would prove that a connection exists.
2. Determine that the subterranean water is more closely related to the stream than the surrounding aquifers.
    a. Determine the direction of the streamflow.
    b. Determine the direction of the subterranean water flow.
    c. Determine that the subterranean water has a chemical composition which is similar to that of the stream.
3. Utilize this information to chart zones of appropriable subflow.

AREAS WHERE SUBFLOW MAY EXIST

Chapter 2 provides a discussion of the characteristics which define perennial and intermittent streams and identifies various areas within the Gila River watershed where a hydraulic connection between the stream and the subterranean waters is known to exist (PLATE 1). As the modified flow net analysis is applied within various hydrographic survey reports (HSR), DWR will complete a detailed analysis of each stream reach to further refine the existing knowledge of where these areas of interaction occur. Since the time variable is not a consideration in determining the subflow areas, any stream reach which flows seasonally and establishes a connection to a subterranean water course should be considered for a refined analysis by DWR.

SUBTERRANEAN WATER IN RELATION TO THE STREAM

The next step in this process is to determine if the subterranean water is more closely related to the stream or to the surrounding aquifers. The Supreme Court has stated that subterranean water is more closely related to the stream if it is of the same gradient, flows in the same direction and is composed of a similar chemical makeup. To begin a comparison between the subterranean waters and the stream, the criteria which may be used to define the stream and its direction must be established.

Definition of the Stream

The Arizona Supreme Court has chosen to use the surface stream for a basis of comparison in a definition of subflow. The stream is perceived to be a well known, definable geographic feature due to the fact that it exists on the surface of the land and can be easily observed. However, a discriminate description of the stream is difficult to obtain due to its dynamic nature; any definition might vary depending on the date of the observation. To begin a comparison, then, a strict definition of the stream is required. Specifically, this should define relatively stable stream boundaries and their location.

The stream reaches mentioned in Chapter 2, PLATE 1, which will be analyzed based upon the requirements of the Supreme Court's opinion, are composed of channels that shift from side to side with moderate to high flow events. These flow events are generally contained within "principal" or dynamic flood channel boundaries. The principal channel boundary has been defined as a floodplain channel in which the stream attempts to gain dynamic equilibrium (Graff, 1988). Low flow dynamic channels work their way back and forth across a larger defined principal channel and, given time, cut away at the channel banks on the outside of meanders. Furthermore, large changes to the physical characteristics of the river can occur during flood flows when the force of larger volumes of water with large amounts of sediment load quickly alter a channel's dimensions. These changes, whether they happen slowly from normal flows or quickly from extreme flood flows, may result in the movement of the principal channel boundary. However, the establishment of this principal channel does encompass most of the shifts in the streamflow. Furthermore, the principal channel is discernable on aerial photography. Any additional analysis required by DWR to determine the direction of streamflow can be made from the coordinates of the midpoint of the banks and are readily computed through the use of DWR's Geographic Information System.

Direction of Streamflow

From a cursory glance, an analysis of the stream's direction seems to be a simple matter of obtaining the streamflow direction at a discrete point. But, although the direction of the stream can be determined in this fashion, it does not mean that the flow direction thus derived is readily comparable to that of the subterranean water. Typically, subterranean water exists and flows though a volume of strata that is at least an order of magnitude larger than the volume of space occupied by the stream. In the San Pedro River for example, the area of the basin fill which contains subterranean water is approximately 2,300 square miles while the principal channel of the streams only occupies about nineteen square miles. Additionally, the depth of subterranean water is not measured in feet, as for surface streams, but in hundreds of feet.

In contrast to the lingering, seemingly deliberate flow of the subterranean water, the stream is responsive to more subtle forces, appearing to be oscillating wildly in comparison to the meandering of the subterranean water. To adequately compare the flow direction the "oscillations" of the stream will need smoothing. In other words, the conditions which force the stream to "oscillate" will be filtered out, resulting in a flow direction that would exist if the scale of observation were the same as for the subterranean flow. A straight line approximation of the stream's direction can be made by eye but a more precise method is required. Since the coordinates of the stream are essentially statistical data, a functional approximation of stream direction can be made. One simple functional approximation often used to smooth statistical data, such as the coordinates of a stream, is called the method of least-squares. A detailed explanation of the method of least-squares is found in APPENDIX B.

Implementation of the least-squares method results in a series of straight lines which approximate the stream course but provide a reasonable direction line for a basis of comparison to the subterranean water flow direction. Figure 4-1 shows a stream course whose direction has been "filtered" through the method of least squares. The filtered stream direction is shown by the straight lines within the dynamic channel boundary.

Direction of Subterranean Water Flow

As discussed in Chapter 2, subterranean water flows in a direction which is controlled by the gradient of the water table. The first step in determining the apparent flow direction is to establish the current water level of the subterranean system. These water levels define the hydraulic gradients which in turn control the flow direction. Typically, hydraulic gradients are represented by lines of equal potential, in this case, lines of equal elevation. Figure 4-2 displays the contour lines which represent points of

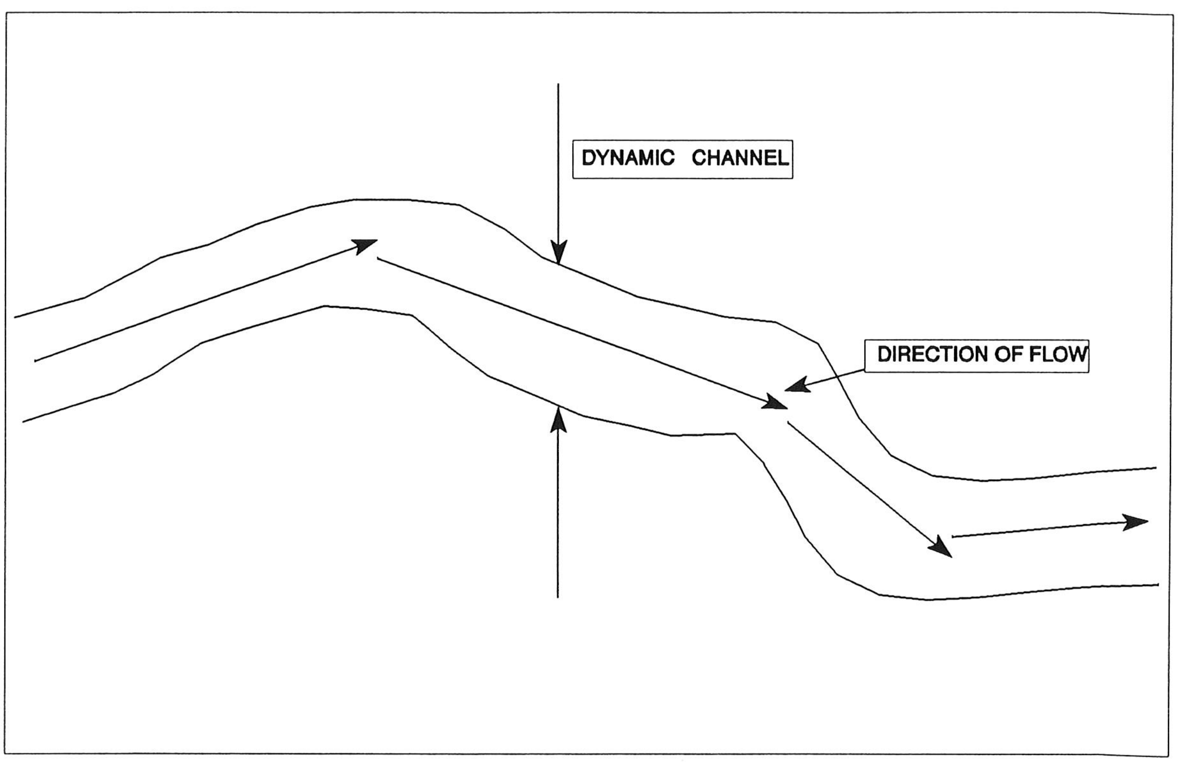


Figure 4-1. Diagram of a dynamic stream channel showing the direction of stream flow.

equal elevation.

The Arizona Supreme Court specifies that the general direction of subflow should be more with the direction of the stream than to or from the stream. Because the flow direction of subterranean water is defined by the gradient of the water table, an examination of the gradients will assist in yielding a technical determination which meets the Court's specification for subflow. Although a subterranean water table comprises a complex surface, a simplified analysis can be executed by comparing the subterranean water surface slope in two directions at any given point. Figure 4-2 displays an example of the relative magnitude, indicated by the size of the arrow, of the slope in two directions at different locations on the water table surface. In this case, the slope of the water table which is in a direction pointing perpendicular to the stream (the perpendicular slope) can be compared with the slope which is in a direction parallel with the stream (the parallel slope). The larger slope at each point exerts more control on the flow direction than does the smaller slope. At some point, the slope of the water table in the direction parallel to the stream will be equal to the slope which is perpendicular to the stream. Figure 4-3 shows this relationship. From that point, the flow of the subterranean water is more in the same direction of the stream than flowing toward the stream. Figure 4-4 shows that past this equilibrium point, the slope of the water table in the direction parallel to the stream is larger than the slope which is perpendicular to the stream.

From another perspective, a line representing the flow direction defines this progression in the slope change of the water table (Figure 4-5). The point at which the slope changes from being predominately perpendicular to the stream to being predominately parallel to the stream is the point where the flow line forms a 45 degree angle to the direction of the stream. DWR concludes that this also provides the most common-sense determination of where the water begins to flow more with the stream.

To define a line which delineates where subterranean water flows in the same general direction as the stream, various flow direction lines can be tested to find the point where the flow line turns to be within 45 degrees of the stream's direction. A simpler solution, however, is to find the point on a contour line where a tangent line forms a 45 degree angle to the streamflow direction. This approach is illustrated in Figure 4-6.

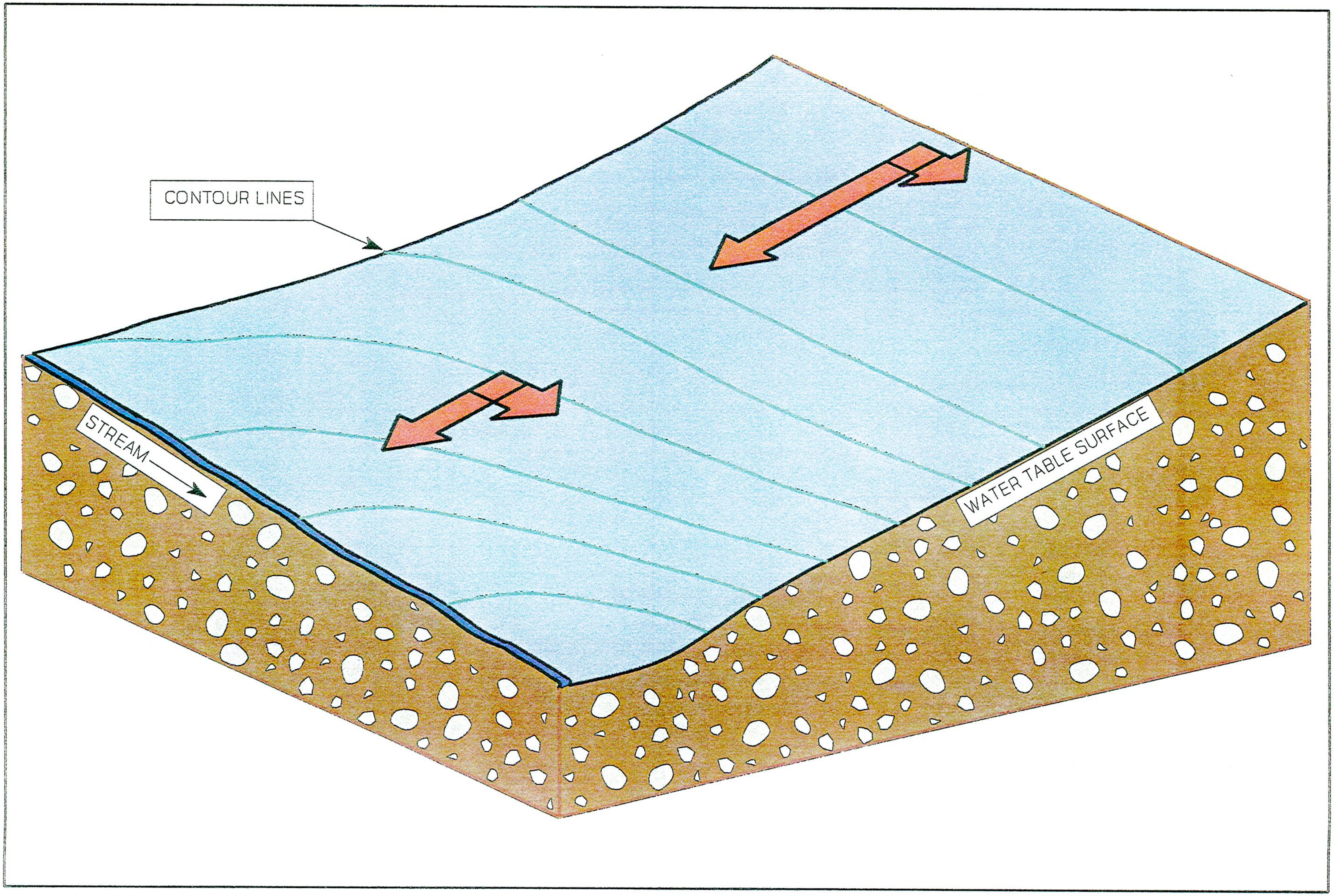


Figure 4-2. Block diagram showing the relative magnitude of the water table surface slope.

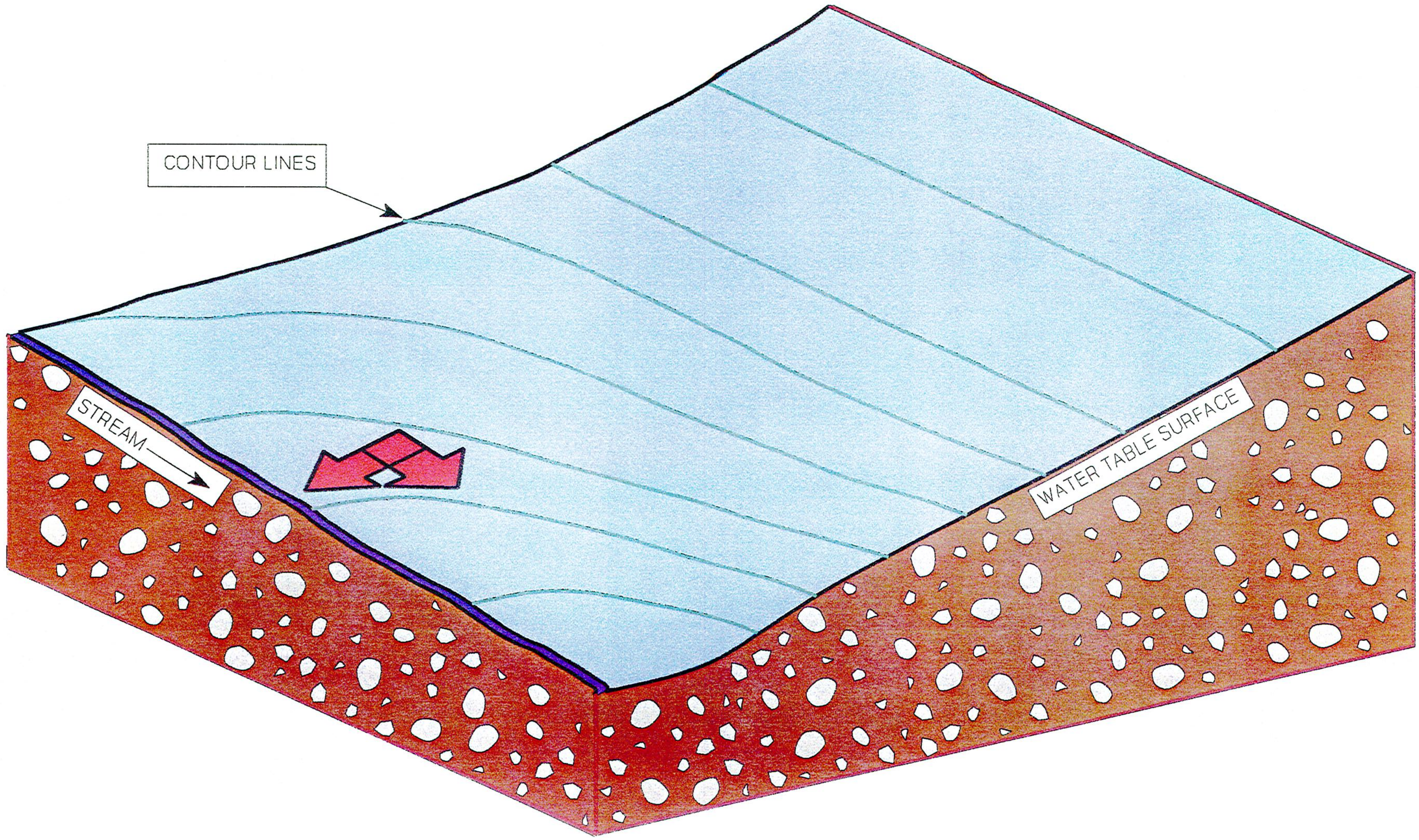


Figure 4-3. Block diagram of a water table surface showing one point where the relative magnitude of the surface slope is equal both down stream and toward the stream.

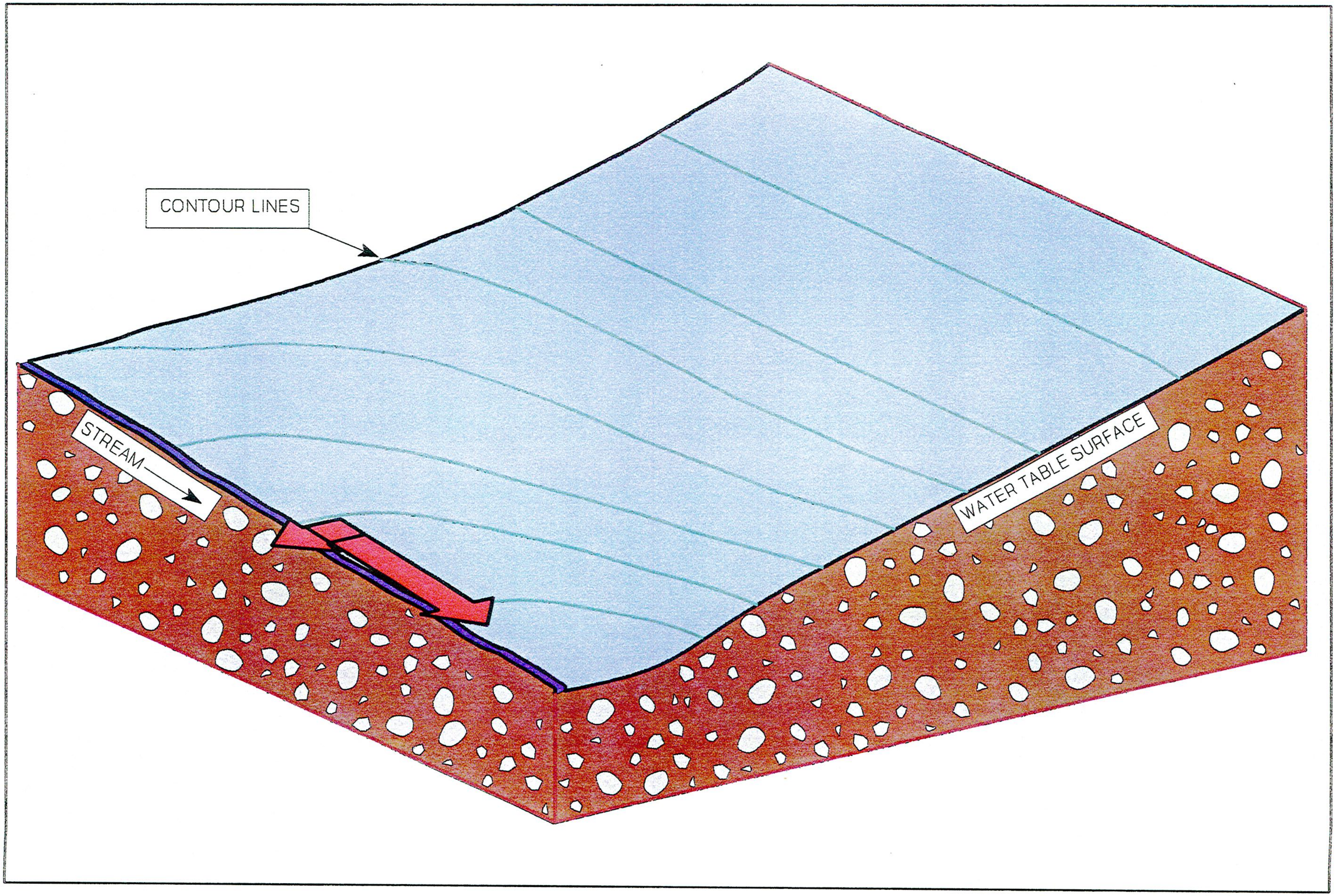


Figure 4-4. Block diagram showing point where the realtive magnitude of the water table surface is mainly with the stream.

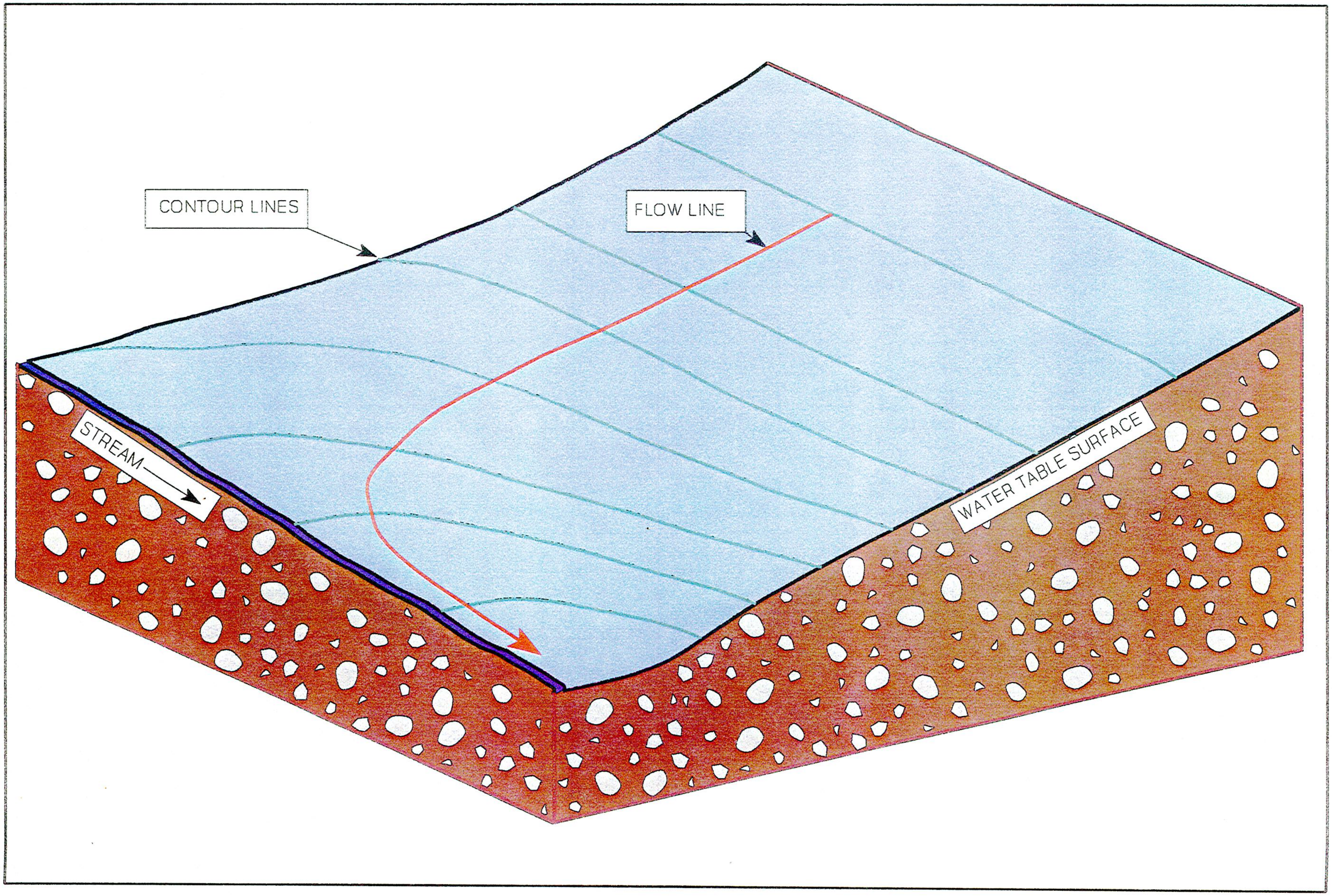


Figure 4-5. Block diagram showing that the direction of flow (red line) is perpindicular to the contour lines and gradualy changes from flowing toward the stream to flowing with the stream.

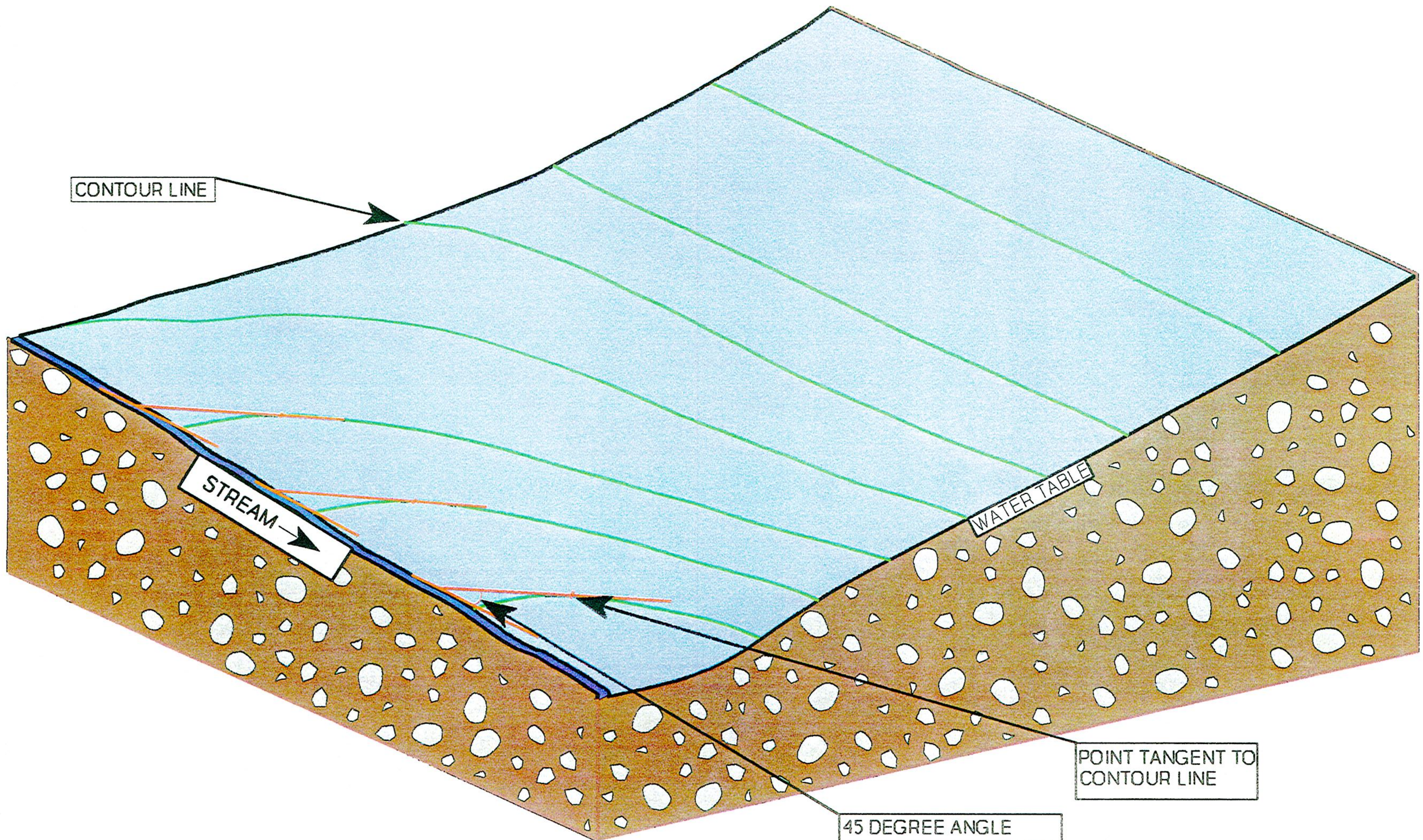


Figure 4-6. Block diagram showing method of selecting point where subterranean flow becomes more like the stream flow. This is accomplished by selecting the point on a contour line which is tangent to a line 45 degrees to the direction of stream flow.

Chemical Composition of the Subterranean Water

As an additional test to determine existence of subflow, the Arizona Supreme Court has stated that the chemical makeup of the subterranean water can be analyzed to see if it is similar to that of the stream. Knowledge of the chemical character of the water is important in determining whether the dominant source of the subterranean water is from the stream or tributary aquifers.

Although chemical sampling of some wells can prove useful, it is only valuable as a validity check for general areas of appropriable subflow, not for the initial determination of these areas. DWR intends to utilize the available data to sample the chemical makeup of some wells, but sampling the chemical composition of the water within every well is beyond the resources of a public funded discovery procedure. Therefore, DWR must leave the testing of the chemical composition of specific wells up to the individual well owner.

It should be noted that the similarity of chemical compounds from a well and a surface stream does not always present clear and convincing proof that the two samples were derived from the same water source. Metzger and Loeltz (1973) cite an example of two wells, one having as its source the Colorado River and the other having as its source mountain front recharge near Kingman, Arizona, where the chemical composition of the water was very similar. On the other hand, these same authors (Metzger and Loeltz, 1973), also state that while groundwater recharge is chemically altered by several processes, the water generally retains some characteristics of the water in the stream.

4.2 AREAS OF APPROPRIABLE SUBFLOW

Implementing the criteria of the modified flow net analysis determines the geographic location of the appropriable subflow zones. This area, called the accounting surface, classifies wells located within to be pumping appropriable subflow. Although the term accounting surface was derived from the United States Geologic Survey Open File Report 93-405 (Wilson and Owen-Joyce, 1993), it is defined here as the boundary of the subterranean water which is more closely related to the stream than to the surrounding aquifers. Wells outside of the accounting surface, although they may be pumping some water from the saturated stream alluvium, are not considered to be pumping appropriable water. The detailed methodology used to actually delineate the accounting surface is presented in APPENDIX B.

4.3 MODEL REQUIREMENTS AND CONSIDERATIONS

A well by well determination of appropriability is not a viable solution when using the modified flow net analysis. This model requires data from a broad area to be statistically sound, while data from a single, isolated well has little plausibility within a hydrologic determination. Because numerous wells must be sampled for the modified flow net analysis, a geographic boundary between and around the sampled wells is essentially drawn. At this point, the appropriability of all wells can be determined based upon their location relative to this boundary.

The only well data required by the modified flow net analysis is static water level elevation. This data is then used to construct the geometry of the subterranean water surface. The exclusion of a time/volume test renders well data such as transmissivity and storage coefficient useless. These parameters depend upon either time or volume to be translated into a meaningful determination of groundwater/surface water interaction. Modeling a subterranean water table surface is the only appropriate approach when attempting to calculate an accounting surface while ignoring time and volume parameters. The modified flow net method, by analyzing the magnitude of subterranean water surface gradients, can determine the geographic location and extent where appropriable subflow exists without a time or volume related variable.

To construct the geometry of the subterranean water surface, a wide segment of the well population will initially need to be studied. Current water level information from a large number of wells may need to be acquired through a direct measurement by DWR. The quality and reliability of the data for each well will be ranked based on the known hydrologic and geologic characteristics of the area. The lower quality data would probably only be used in areas where the high quality data is sparse. DWR expects that an extensive analysis will need to be completed for an entire watershed before the accuracy of a modified flow net determination can be upheld.

Because this model utilizes well elevation data as the main input to predict the flow characteristics of subterranean water, it produces an image of the subterranean water surface as it exists at the time the well data was collected. The best input data for the model will likely come through field measurements made by DWR. Consequently, the accounting surface produced will reflect current conditions. Many of the data points may be derived from areas in which the shape of the water level surface has been significantly altered through the course of development. An analysis of the subterranean water surface prior to development, however, would require a large amount of accurate water elevation data gathered before development occurred. Such data simply does not exist. Furthermore, wells are generally constructed one at a time through the course of development, and are usually pumped throughout that development, making modeling an accounting surface based on pre-development conditions virtually impossible. Areas which contain wells that have changed the gradient of the water level surface of the saturated younger alluvium may be included within the accounting surface whereas, in many such cases, the shape of the predevelopment water level surface would have excluded some of these wells.

Once the modified flow net analysis has progressed to the point that the movement of subterranean water in relation to the stream has been established, the actual location and existence of the stream becomes immaterial for the sake of modeling the accounting surface. Nevertheless, in some instances, the edge of the accounting surface may actually be inside of the dynamic stream channel boundaries. Because the purpose of the test is to find the subterranean water that is actually part of the stream, however, the presumption can be made that the stream itself should be within the accounting surface. For this reason, in situations when the modified flow net analysis places the accounting surface inside of the dynamic channel boundary, the accounting surface will be moved to the edge of the dynamic channel boundary.

The next chapter of this report will discuss the use of the modified flow net analysis within the San Pedro River watershed and whether its use is appropriate for the various geologic conditions found throughout the Gila River watershed.

CHAPTER 5: EXAMPLES OF IMPLEMENTATION

As part of the court hearing on October 7, 1993, in re the General Adjudication of All Rights to the Water in the Gila River System and Source, the Arizona Department of Water Resources (DWR) was directed to determine if one criteria or multiple criteria are needed for the delineation of subflow within the Gila River adjudication proceedings. In addition, the Court directed DWR to limit any analysis based upon well data to wells that are located within the San Pedro River watershed.

DWR's evaluation has found that the modified flow net method presented in Chapter 4 of this report is an appropriate method for use throughout the watershed with special consideration for each of the four groundwater/surface water system types identified in Chapter 2. Data requirements of the proposed method and the special considerations for these four groundwater/surface water system types will be discussed in this chapter along with some examples for the system types that are found within the San Pedro River watershed.

5.1 MODIFIED FLOW NET ANALYSIS DATA REQUIREMENTS

The modified flow net analysis is essentially an analysis of the surface of a groundwater system, and the evaluation is most accurate when a large amount of appropriate water level data is available to use in constructing this water surface. Because the water levels in wells often change over time, the most appropriate well data will consist of data which is collected at one point in time. In implementing this model within future adjudication investigations, DWR will need to directly measure a large number of wells to acquire an appropriate amount of water level data.

The well data used in the following examples was derived from the Groundwater Site Inventory (GWSI) and the DWR well registration databases. This water level data is not representative of a selective time frame, nor was the well elevation or location data necessarily accurate, in many instances being derived from topographic maps rather than being surveyed. For these reasons, the examples presented here should be considered for illustrative purposes only. An actual watershed wide analysis may result in a different accounting surface for these areas.

5.2 ALLUVIAL VALLEY STREAMS WITH CONFINED ZONES

The area chosen for this illustrative example includes a reach of the San Pedro River beginning at Mammoth and ending at a point approximately 8 miles south of this community. This portion of the San Pedro River is an intermittent stream that flows in an alluvial basin. It is surrounded by the younger alluvium and underlain by a confined aquifer. Wells in this area either draw water from the shallower younger alluvium or from the deeper confined aquifer. The confined aquifer is located at a depth ranging from 550 to 1370 feet below the land surface (Roeske and Werrell 1973). Due to hydraulic pressure, this confined zone sometimes produces static water levels which are similar to the water levels found in wells which draw from the younger alluvium only.

This confined aquifer is not considered to have a direct hydraulic connection to the stream and is therefore not an appropriable source of subflow. However, in two dimensional space, portions of the confined aquifer will be considered within the accounting surface. To utilize the modified flow net analysis in this area, wells which were over 500 feet deep and located in or near the confined area as delineated by USGS Open File Report 80-954 (Jones, 1980) were suspected of penetrating into the confined zone and were not considered in the analysis. A list of wells which were used in this analysis is included in APPENDIX C.

The accounting surface resulting from an analysis of this type will then pertain only to wells which are pumping water from the younger alluvium and not the underlying confined aquifer. However, when considering the actual wells which may be pumping appropriable water, data on well depth does not define which wells are clearly pumping from the confined zone. The casing of a deep well may be perforated or broken at any elevation and can therefore be drawing water or a percentage of water from the younger alluvium. DWR proposes that all wells located within the accounting surface overlying a confined aquifer be considered to be pumping appropriable subflow. Any individual well owner, however, should have the opportunity to have the well designation changed by proving that the well is pumping water from the confined aquifer.

Other than removing wells with a depth of over 500 feet from the analysis, development of the accounting surface in this area is as described in Chapter 4 and APPENDIX B. A least-squares fit of the center of the stream channel yields three direction lines from which to draw a 45 degree tangent to the contour lines (Figure 5-1). The correlation coefficients of these lines moving downstream are -0.99, -0.97, and -0.91. The average distance from the channel center to the edge of the accounting surface is 845 feet on the east side and 864 feet on the west side of the river. The accounting surface in some instances fell within the dynamic channel and was extended to the edge of the dynamic channel. A chemical analysis of selected wells was not conducted in this example solution. The accounting surface and dynamic channel for this reach is shown in Figure 5-2.

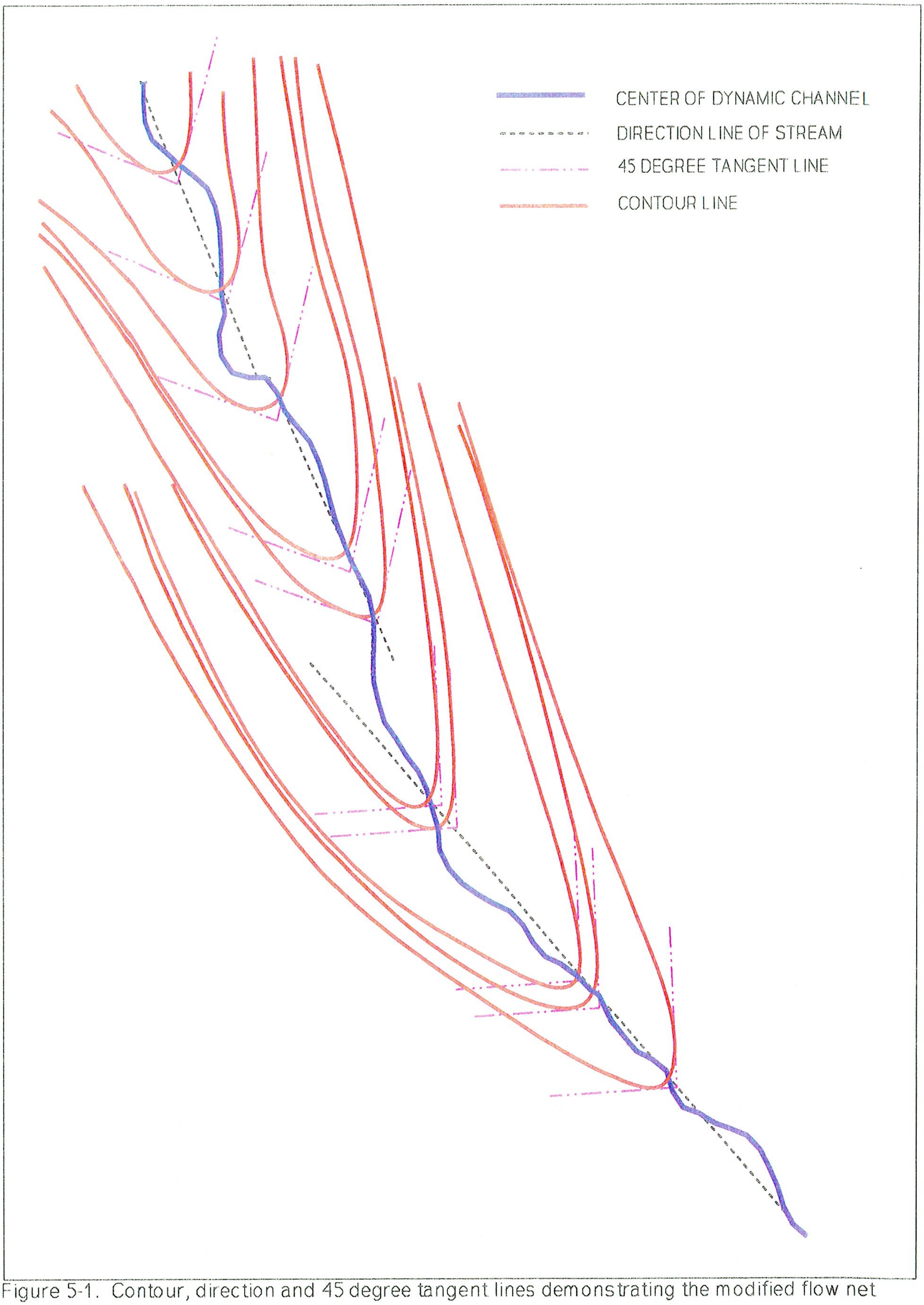
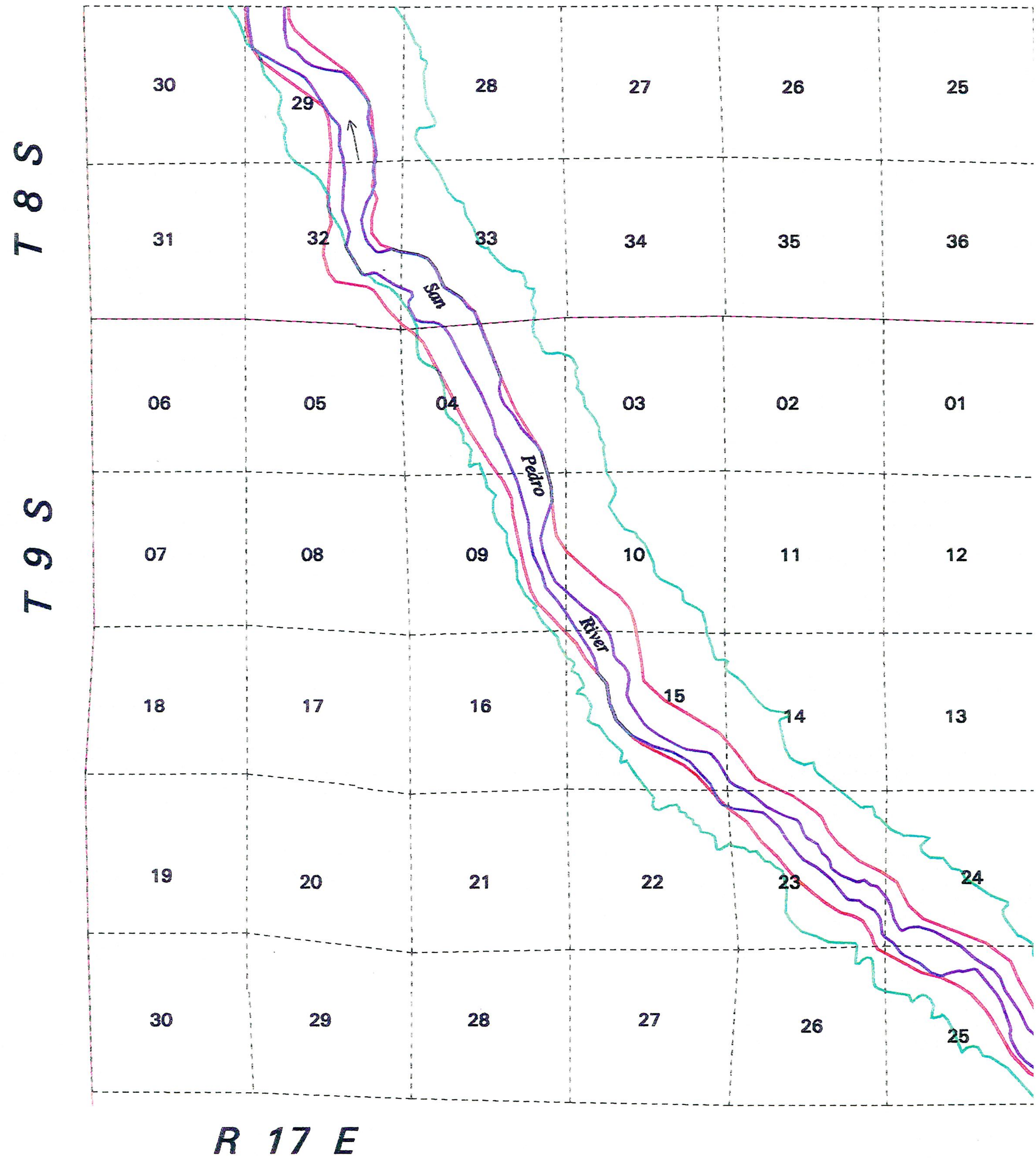


Figure 5-1. Contour, direction and 45 degree tangent lines demonstrating the modified flow net analysis between Redington and Mammoth.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T 9 S
R 17 E
San Pedro River
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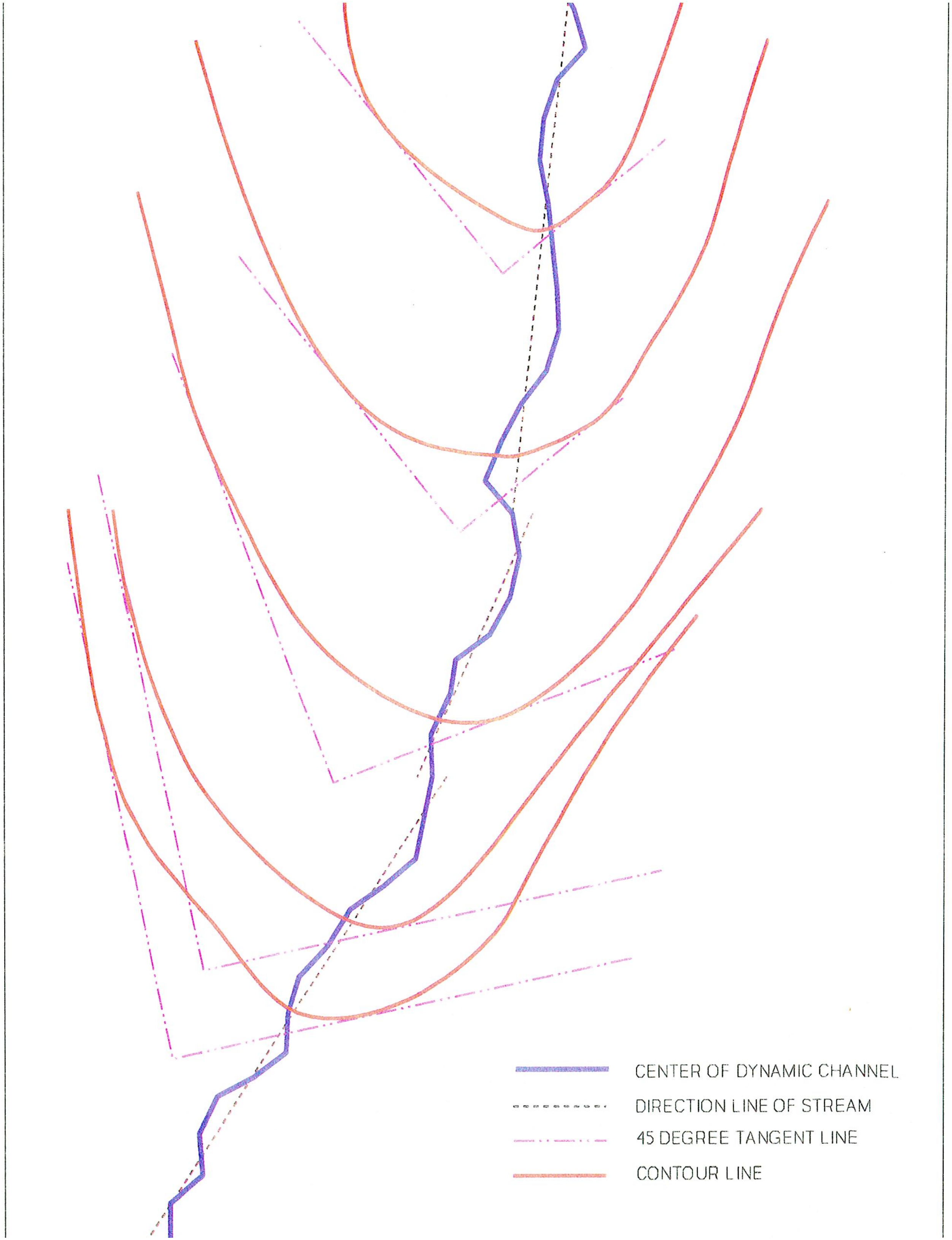
Township and Range

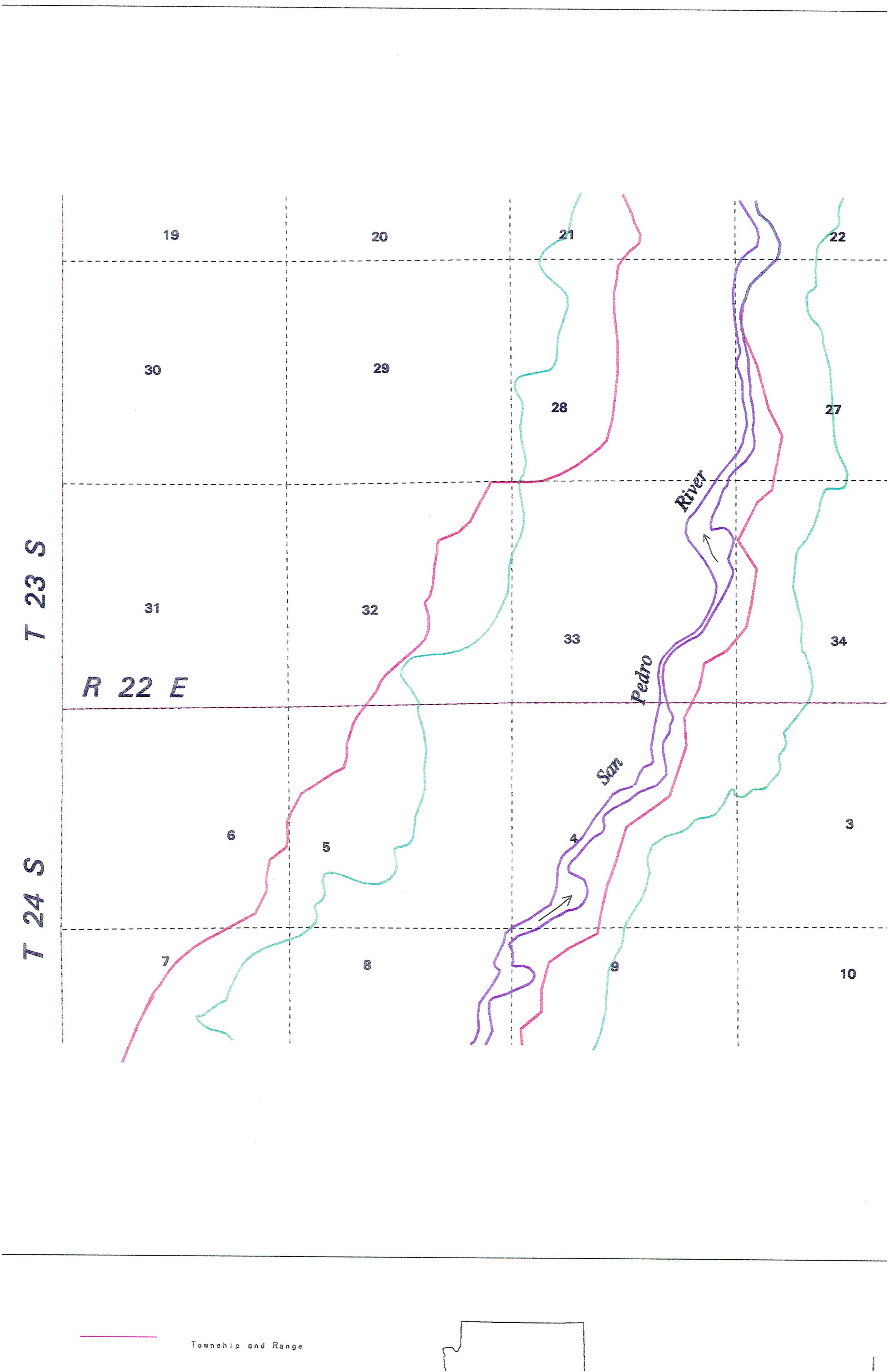
The study area chosen for this example is a 3½ mile long reach of the San Pedro River which begins about 1½ miles south of state highway 92 near Palominas. This portion of the San Pedro River is composed of a perennial stream that flows in an alluvial basin and is underlain and bounded by the younger alluvium. This area encompasses a number of developed irrigation operations which have been supplied by wells for many years.

Although portions of this reach are underlain by a discontinuous confined zone, it is used here as an example of an alluvial valley stream without a confined layer. In the Palominas area, the water resource located below the confined layer has not been significantly developed as in other areas containing confined layers within the watershed. Additionally, for the sake of illustrative purposes, existing well data is abundant within this area, allowing DWR to define a preliminary accounting surface without collecting field data. As demonstrated in the previous example, the modified flow net analysis can easily handle the existence of confined zones underlying the river aquifer if the location and depth of the confined layer is known. In the Palominas area, the confined layer is located at a depth of about 200 feet below the land surface (Roeske and Werrell, 1973). Wells located within or near the confined area as delineated by United States Geological Survey (USGS) Open File Report 80-1192 (Konieczki, 1980) were discounted from the analysis. A list of wells which were used in this analysis can be found in APPENDIX C.

Again, except for discounting wells over 200 feet deep from the analysis, the development of the accounting surface follows the methodology explained in Chapter 4 and APPENDIX B. A least squares fit of the dynamic channel center line produced three direction lines, with one special consideration. Due to the fact that the northern portion of this reach contains numerous inflection points on a typical coordinate system (with the east-west coordinate alternately increasing then decreasing in value) an alternative coordinate system was used in evaluating this portion of the stream. This involved simply rotating the north-south and east-west ordinates 45 degrees in a clockwise direction. The correlation coefficients for the three segments, going downstream, are 0.99, 0.94, and -0.98. Figure 5-3 shows the resulting direction and


CENTER OF DYNAMIC CHANNEL
DIRECTION LINE OF STREAM
45 DEGREE TANGENT LINE
CONTOUR LINE

4,490 feet on the west side. This large difference in distance to the accounting surface demonstrates the fact that groundwater development on the west side of the river has created a regional depression of the water table, flattening the gradient of the subterranean water. The accounting surface for this reach is shown in Figure 5-4.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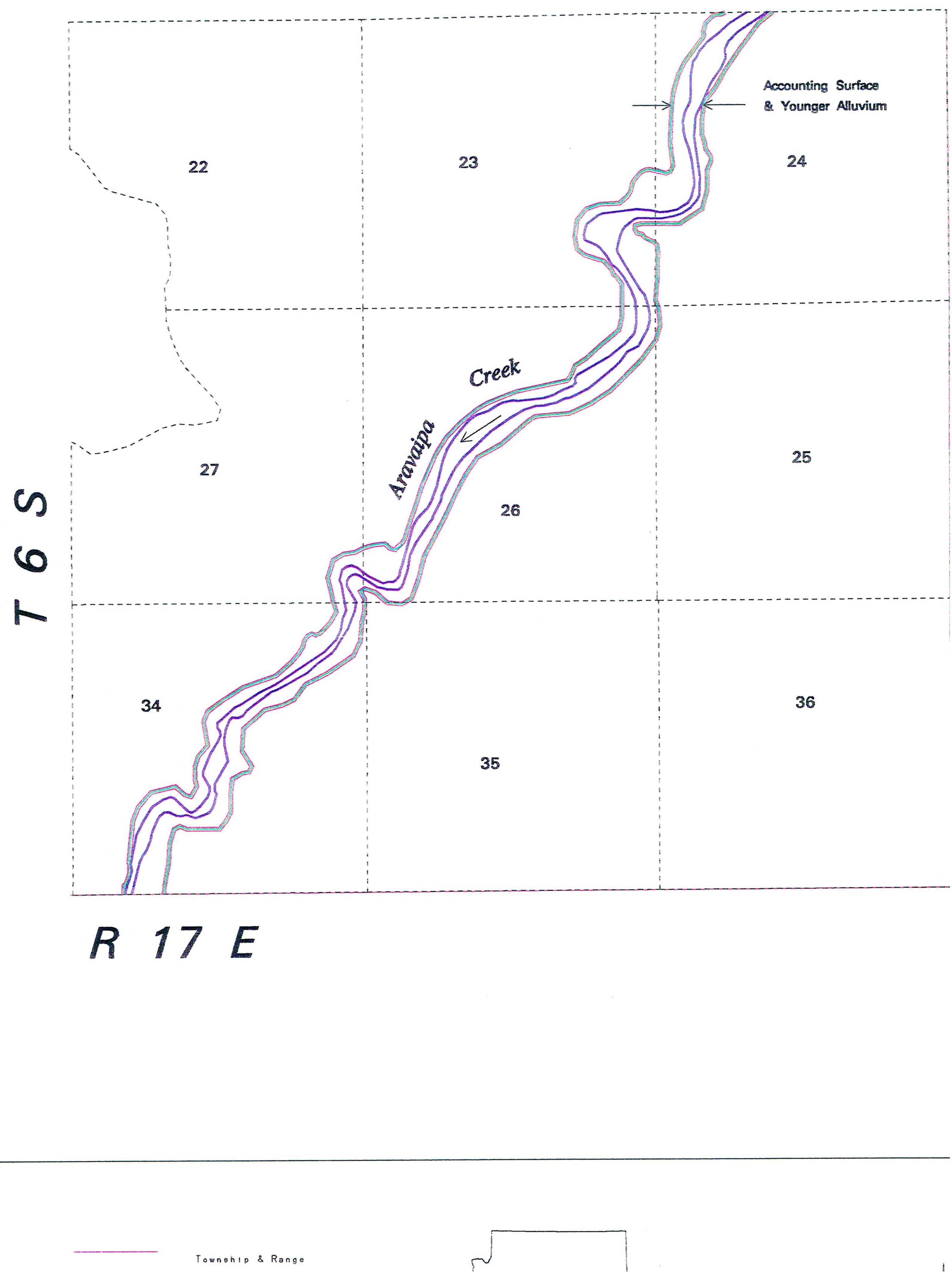
T 23 S
T 24 S
R 22 E
San Pedro River
Township and Range

The stream reach used here to illustrate the modified flow net analysis in a bedrock stream is a 3½ mile long section of Aravaipa Creek beginning near the end of Aravaipa Canyon. This area consists of a narrow canyon floor containing domestic and irrigation uses overlying the younger alluvium. The younger alluvium is itself bounded on the sides and bottom by consolidated tributary aquifers or impermeable bedrock. The hydraulic connection between the younger alluvium and any consolidated tributary aquifers is limited to areas of faults and fractures. No wells in this area are known to derive water from the tributary aquifers.

An analysis of the water levels in the wells in this area shows that subterranean water elevation is nearly the same as the elevation of the stream. The flow direction is also nearly the same as that of the stream. In this case, no further steps of the modified flow net analysis need to be completed. The flow direction and elevation of the subterranean water meets the test of being more with the stream when water levels equal that of the stream. The line between subterranean water which is flowing in the direction of the stream is truncated by the close proximity of the impermeable bedrock. The accounting surface and the impermeable bedrock boundary are consequentially the same. The accounting surface for this reach is shown on Figure 5-5. The wells considered in this analysis are listed in APPENDIX C.


Accounting Surface
& Younger Alluvium
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23
24
Creek
Aravaipa
27
26
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34
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36
T 6 S
R 17 E
Township & Range

No areas near mountain front streams have been developed within the San Pedro River watershed, therefore no physical example of the modified flow net analysis can be made within this report. In general terms, a mountain front stream is essentially a bedrock canyon stream which transitions to an alluvial valley stream with a younger alluvium. In many cases, the alluvial valley stream portion of a mountain front stream is a losing reach which eventually transitions to an ephemeral stream, losing connection with the subterranean water. When this happens, the losing reaches will produce an inverted contour line, with the vertex of the contour pointing downstream rather than upstream as in the previous examples. The modified flow net analysis can still be used to find the 45 degree tangent to the contour line regardless of the contour lines orientation up or down stream. An example of this type of analysis is shown in Figure 5-6.

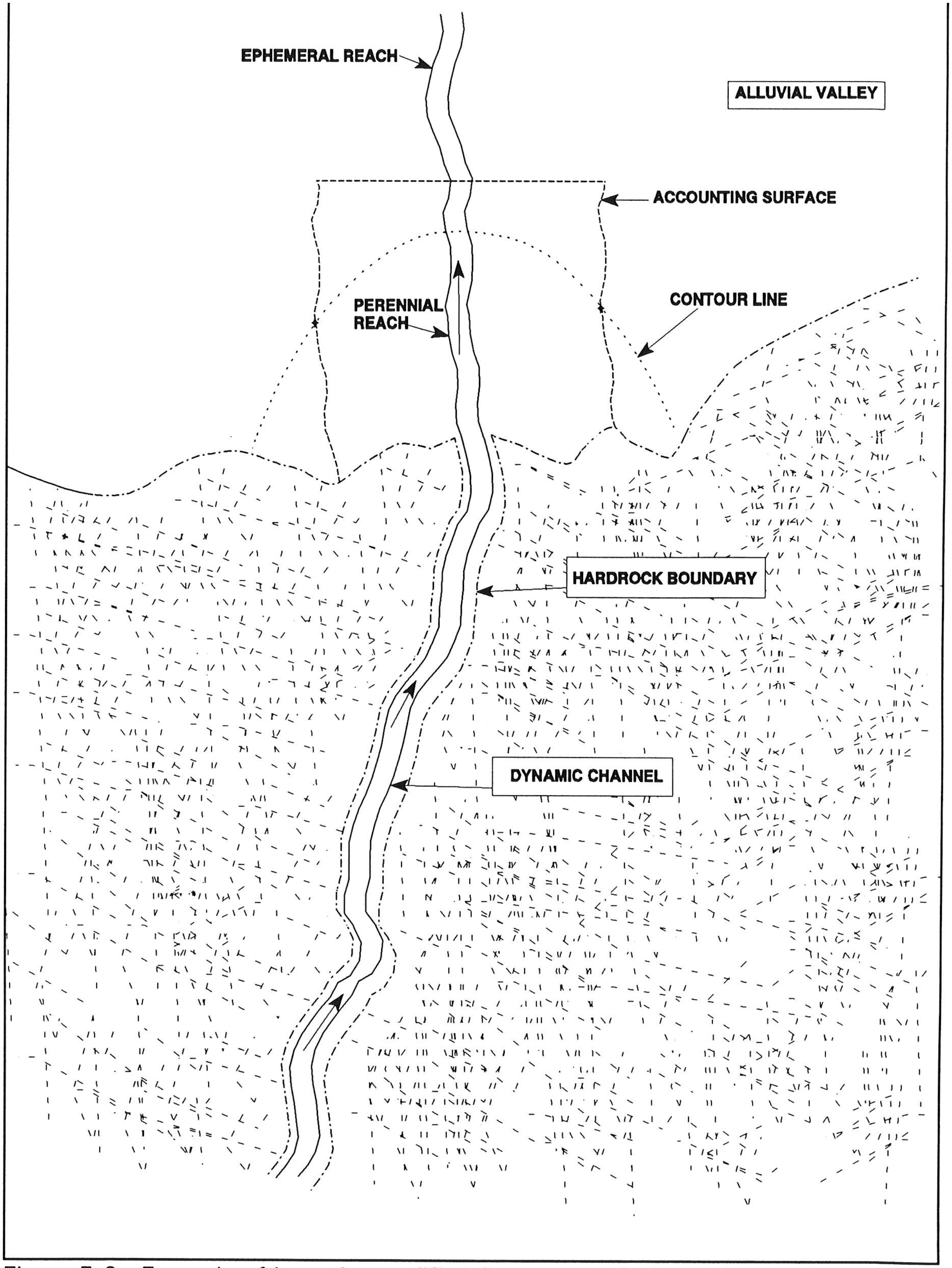

Figure 5-6. Example of how the modified flow net analysis can be used on

The perennial and intermittent stream reaches shown in Chapter 2, PLATE 1 all fall within one or more of the categories mentioned above. The zone of appropriable pumping or the accounting surface for each of these reaches can be computed by the modified flow net analysis using the specific requirements of each stream type. Listed below by stream reach classification are some of the perennial or intermittent streams in the Gila River watershed which may contain subflow. This classification was based upon the listed perennial or intermittent streams in Brown, Carmony, and Turner (1978) and does not include some of the smaller stream reaches located away from developed areas. PLATE 3 illustrates more precisely where the classified stream reaches are located. These classification are subject to change as detailed hydrographic survey report (HSR) investigations are completed in each watershed.

<u>Alluvial Valley Streams</u>

A. Upper Gila River
  1. Duncan Valley to Gila Box segment
  2. Calva to San Carlos Reservoir segment
  3. Winkelman to Kelvin segment
  4. Portions of San Francisco River
  5. Portions of Blue River
  6. Portions of Eagle Creek
  7. Portions of Bonita Creek
  8. San Carlos River near San Carlos Reservoir
  9. Portion of (west) Ash Creek
  10. Portion of Mineral Creek

B. Lower Gila River
  1. Confl. w. Salt River to Cotton Center
  2. Yuma segment
  3. Portion of Queen Creek
  4. Salt River below Phoenix to confl. w/ Gila River

C. San Pedro River
  1. Hereford to St. David segment

3. Mammoth to confluence with Gila River segment
4. Babocomari River
5. Hot Springs Canyon
6. Aravaipa Creek - Aravaipa Valley segment
7. Aravaipa Creek - San Pedro River Valley segment

D. Salt River
1. Portions of Salt River and tributaries above confl. w/ Canyon Creek
2. Stewart Mtn Dam to Granite Reef segment
3. Portions of Cherry Creek
4. Pinal Creek
5. Tonto Creek - Gisela to Roosevelt Reservoir
6. Rye Creek
7. Deer Creek

E. Santa Cruz River
1. Nogales to Arivaca Junction
2. Tucson segment
3. Marana segment
4. Pantano Wash
5. Portion of Cienega Creek

F. Verde River
1. Portions of Verde River from Sullivan Lake to confl. w/ Salt River
2. Mint Wash
3. Portion of Oak Creek
6. Portion of Wet Beaver Creek
7. Portion of West Clear Creek
8. Portions of East Verde River

<u>Alluvial Valley Streams with Confined Aquifers</u>

A. Upper Gila River
1. Safford Valley Segment

B. San Pedro River

3. Redington to Mammoth segment

C. Verde River

1. Clarkdale to below confl. w/ West Clear Creek segment
2. Bartlett Lake to confl. w/ Salt River segment
3. Granite Creek near confl. w/ Verde River segment
4. Lower portion of Oak Creek
5. Lower portion of Wet Beaver Creek
6. Lower portion of West Clear Creek

<u>Bedrock Canyon Streams</u>

A. Upper Gila River

1. Gila Box segment
2. San Carlos Reservoir to Winkelman segment
3. Kelvin to Ashurst Hayden Dam segment
4. Major portions of San Francisco River
5. Major portions of Blue River
6. Major portions of Eagle Creek
7. Portion of Bonita Creek
8. Portions of (west) Ash Creek
9. Devils Canyon
10. Matilda Wash

B. Lower Gila River

1. Cave Creek
2. New River
3. Upper portions of Hassayampa River
4. Portion of Queen Creek

C. San Pedro River

1. Aravaipa Creek - Aravaipa Canyon segment

D. Salt River

1. Major portions of Salt River and tributaries above confl. w/ Canyon Creek
2. Near Confl. w/ Cherry Creek segment

[illegible] Tonto Creek and tributaries above Gisela

E. Santa Cruz River

- 1. Redrock Canyon

F. Verde River

- 1. Major portions of Verde River from Sullivan Lake to Clarkdale
- 2. Portions of Verde River near confl. w/ West Clear Creek to confl. w/ Salt River
- 3. Major portions of East Verde River
- 4. Fossil Creek
- 5. Portions of (lower) Sycamore Creek
- 6. Portion of Deadman Creek
- 7. Upper Portion of Oak Creek
- 8. Upper Portion of Wet Beaver Creek
- 9. Upper Portion of West Clear Creek

F. Agua Fria River

- 1. Portion of Agua Fria River
- 2. Ash Creek
- 3. Sycamore Creek
- 4. Yellow Jacket Creek

<u>Mountain Front Streams</u>

A. Upper Gila River

- 1. San Carlos River above Town of San Carlos
- 2. Cave Creek
- 3. Portion of Mineral Creek
- 4. (east) Ash Creek

B. Lower Gila River

- 1. Hassayampa River below Wickenburg

C. San Pedro River

- 1. Redfield Canyon
- 2. Putnam Wash

1. Pinto Creek

2. Greenback Creek

E. Santa Cruz River

1. Sonoita Creek
2. Sabino Canyon
3. Tanque Verde Creek
4. Parker Canyon
5. Rincon Creek
6. Portion of Cienega Creek
7. Arivaca Wash

F. Verde River

1. Portion of Deadman Creek
2. Portions of (lower) Sycamore Creek

G. Agua Fria River

1. Portion of Agua Fria River
2. Big Bug Creek

The Arizona Supreme Court in *Southwest Cotton* made the first extensive examination of subflow. In its opinion, it included a number of subjective guidelines. Those guidelines were difficult to implement and, as a consequence, this legal principle has gone largely ignored until confronted by the general adjudication. The Court's revisitation of the issue in its July, 1993 opinion reiterated *Southwest Cotton's* view that subflow is only the underflow component of the stream or underground water that is closely associated with the stream. The Court included additional guidelines for the identification of subflow, but those guidelines are also very subjective. Apparently, the Court did not intend that its guidelines would provide the final answer for subflow, but instead were provided in the opinion to assist the trial court in developing a new criteria on remand. To assist the trial court in this assignment, DWR has focused on a technical assessment of the hydrologic principles contained within the Supreme Court's recent opinion and the available tests to implement that opinion.

Groundwater and surface water interactions can only occur along stream reaches where the groundwater system at least periodically establishes a hydraulic connection with a perennial or intermittent stream. In stream reaches where the groundwater/surface water interaction has been severed by the development of groundwater resources, it is not practical or even feasible to recreate the connection. Subflow must be defined under current conditions, using current data, to establish the fact of hydraulic connection. If this hydraulic connection does not exist, the impact of pumping wells is not measurable at the stream.

The law, as originally set forth by *Southwest Cotton* and reiterated by the recent opinion, defines appropriable subflow as the known subterranean component of the stream. A physical basis to identify the boundaries of the subterranean component of streams in alluvial valleys does not exist. Consequently, any method devised to describe the extent of a discrete hydrologic entity that does not actually occur must of necessity incorporate an arbitrary or judgmental factor which adequately defines the boundary.

proposition. The potential interference diminishes gradually with increasing distances from the stream. In alluvial valley stream environments, the true nature of subflow is a region within which a certain level of interference is expected to result from pumping wells.

The most scientific method to assess streamflow interference from pumping wells is an analytical method based upon the Theis formula or numeric computer modeling. Either of these methods, however, require specification of a certain period of time for the analysis, and the results can only be put into the context of subflow when compared against a certain threshold of qualifying interference. The opinion criticizes this approach in rejecting the 50%/ 90 day test, but then includes a cone of depression test as indicative of subflow--a test that can only be performed using the same basic methods and assumptions from which the 50%/90 day determination was derived. These statements are not easily reconciled.

If the trial court finds that a time-based interference test is not compatible with the law or for other reasons is not the best test, then geographic tests can be considered. Those tests are intended to identify a specific area within which wells are presumed to be withdrawing subflow. The presumption would be based upon a certain set distance from the stream or upon a natural hydrogeologic feature. A uniform distance from the stream method offers significant implementation and administration benefits. It could incorporate multiple distances coupled with withdrawal criteria as is done under the Oregon method. It could also be specified more generally as a sufficient distance, on average, to prevent undue effect on streamflow or the riparian habitat during the season that the well is pumped. The distance "to prevent undue effect" could be determined from aerial photo or remote sensing analysis as a function of the average width of riparian vegetation in a watershed. Combining elements from interference tests, it could also be based upon an analysis to determine a representative distance within a watershed where wells would be expected to obtain a certain percentage of the withdrawal from the stream during the low streamflow period of the year. Although this method establishes multiple brightlines, it reduces the potential to create large impacts on the stream from wells located just outside the line definition.

hydrogeologic feature that can be associated with the surface stream, such as the younger alluvium. With regard to this possible criteria, the Court again appears to both reject its use in one area of the opinion and require it in other areas. DWR believes that if the Court wants to view subflow as a natural area within which groundwater is closely associated with the stream in terms of elevation, gradient, and flow direction, the younger alluvium provides the best test. Its advantages include the fact that it can be delineated with relative certainty because its lateral extent can be observed from above the ground. It can be readily implemented and will not change over time due to the effects of continuing groundwater pumping. Its disadvantages are that it establishes a "brightline" outside of which pumpage would not be subject to the law of appropriation, regardless of the magnitude of withdrawal and actual effect on the stream. Although in most locations the younger alluvium can be expected to be relatively near the stream, in some areas it can extend outward for over a mile. Geographic tests are subject to the criticism that they are arbitrary, but they are also definitive, bringing final resolution to this issue.

A third approach to the delineation of subflow was developed by DWR in response to our interpretation of the central guidelines outlined by the Supreme Court which do not appear to be contradicted or negated by other guidelines in the opinion. DWR believes that those central guidelines are found on the page of the opinion where the Court states that subflow "turns on whether the well is pumping water that is more closely associated with the stream than with the surrounding alluvium. For example, comparison of such characteristics as elevation, gradient, and perhaps chemical makeup can be made. Flow direction can be an indicator. If the water flows in the same general direction as the stream, it is more likely related to the stream." 857 P.2d at 1246. DWR believes that the modified flow net method described in chapters 4 and 5 of this report carries out these directives. The advantages of this method are that it meets a strict interpretation of the Court's opinion by concentrating on the central directives and avoiding guidelines that appear to be conflicting in the ruling. Its disadvantage is that it is based upon a snapshot of aquifer conditions at a specific instant in time. The delineated distance outward from the stream is influenced by also result in the delineated boundaries of subflow extending to distances exceeding the edge of the younger alluvium.

If time of implementation is considered a relevant criteria, the Court should consider carefully either an interference based approach or a geographic approach. Either of these methods could be readily implemented by DWR based upon information already gathered in existing Hydrographic Survey Reports. If a flow net method of analysis is chosen, however, extensive new data collection will be required before the computer models could be accurately created. Seasonal constraints on the availability of this data could result in delays of 12 to 20 months before a revised appropriability zone could be mapped for the San Pedro watershed. Future Hydrographic Survey Reports would not be delayed beyond normal time projections.

Table 6-1 outlines the advantages and disadvantages of the principal methods for delineating subflow analyzed in this report. The choice between the various methods is not an easy decision. In the final analysis, it probably depends more upon the Court's interpretation of the law than of the practical hydrology of Arizona. DWR's viewpoint, however, is less concerned with precedent and more concerned with a workable system of groundwater/surface management which will survive the continued development of our water resources into the next century. This leads us to conclude that the time/volume interference test, being the most accurate, is the best system. Next, the younger alluvium test, with its natural boundary and ease of implementation, is a dependable methodology with considerable technical merit. Finally, if flow direction and gradient are deemed to be the salient features, the modified flow net analysis provides a workable model upon which to draw the limits of appropriable water under our system of water rights.

TABLE 6-1

PRINCIPAL METHODS FOR DELINEATING SUBFLOW

YOUNGER ALLUVIUM	MODIFIED FLOW NET ANALYSIS	TIME/VOLUME TESTS
ADVANTAGES	**ADVANTAGES**	**ADVANTAGES**
- hydrogeologic feature that is part of the stream stem	- provides instantaneous determination of subflow within strict interpretation of Supreme Court's opinion	- rigorous scientific basis
- can be well specific	- can be well specific	- can be well specific
- appropriate watershed wide	- appropriate watershed wide	- provides extent of impact from uses
- provides a stable, consistent standard through ne, not influenced by cultural activities	- requires only water table elevation data	- predicts the impact of cultural uses
- does not require extensive data collection kisting maps by USGS and DWR)		- numerous analytical solutions
- does not include numeric standard		
- does not necessarily overturn *Southwest tton*		
DISADVANTAGES	**DISADVANTAGES**	**DISADVANTAGES**
- does not determine extent of impact from uses	- number and accuracy of data points directly effects accuracy of test	- number and accuracy of data points directl effects accuracy of test
- not within strict interpretation of Supreme urt's opinion	- influenced by the cumulative impact of all prior cultural groundwater withdrawals	- not appropriate watershed wide
	- requires numeric standard	- requires numeric standard
	- does not determine extent of impact from uses	- not within strict interpretation of Supreme Court's opinion
	- inconsistent through time	
LIMITING ASSUMPTIONS	**LIMITING ASSUMPTIONS**	**LIMITING ASSUMPTIONS**
- well pumping within the Younger Alluvium is ectly impacting surface water flow	- 45^0 is the correct angle of inflection	- Dupuit Assumptions (restrictive assumption that simplify the hydrologic system)

Anderson, T.W., Freethey, G.W., and Tucci, P., 1992, Geohydrology and Water Resources of Alluvial Basins in South-Central Arizona and Parts of Adjacent States: U.S. Geological Survey Professional Paper 1406-B, 67 p.

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Metzger, D.G., Loeltz, O.J., and Irelna, B., 1973, Geohydrology of the Parker-Blythe-Cibola Area, Arizona and California: U.S. Geological Survey Professional Paper 486-G, 127 p.

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This appendix will outline the methodologies used to predict the interaction of pumping wells on a nearby stream. There are four general methods available to analyze these interactions: younger alluvium method, flow net method, analytical methods, and numerical methods. The following discussion is intended to provide the reader with a general overview of the methods available. For a more rigorous treatment of these methods, the texts by Freeze and Cherry, 1979, and Bouwer, 1978, are useful introductions.

A.1 YOUNGER ALLUVIUM METHOD

The younger alluvium method does not quantify the impact of pumping wells on the surface water system, but rather identifies a hydrogeologic feature, the younger alluvium. Withdrawals from the younger alluvium are predicted to have a direct and appreciable effect on streamflow.

The younger alluvium is a distinct hydrogeologic unit. It is relatively homogenous when compared to basin fill or consolidated aquifers, has high hydraulic conductivity and storage coefficient values, and is a mappable geologic unit. The delineation of the younger alluvium is accomplished through detailed field mapping. The USGS and ADWR have mapped the younger alluvium over most of the Gila River watershed. The younger alluvium is a stratigraphic unit that is derived from recent (Quaternary) stream action. The alluvium is identified in the field by it's stratigraphic position, location within or adjacent to active stream channels, and being poorly indurated or unconsolidated. Because the younger alluvium is located within the channel of streams, it is readily identified in the field and on aerial photographs.

The flow net method utilizes flow net analysis to evaluate the direction of groundwater flow and the volume of discharge to the stream or younger alluvium. Flow nets are graphic solutions to hydrologic problems, relying on groundwater elevation data to generate groundwater contours and flow lines. The direction of flow is determined from the hydraulic gradient determined from groundwater contour data used to draw the flow net. Flow lines are drawn perpendicular to the contour lines. The area between flow lines are known as streamtubes. The determination of volume of discharge is accomplished by determining the flow through the area where the streamtube crosses a contour line. If the streamtube is cubic, the discharge across the streamtube is determined by the formula:

$$dQ = K\frac{dh}{ds}dm$$

where dQ = discharge for one streamtube,
K = hydraulic conductivity,
dh = change in head.

Flow net analysis historically is the first step in any detailed analysis of a hydrologic system and only requires the water level elevation (head) data and hydraulic conductivity. However, if the volume of discharge is known, the hydraulic conductivity can be determined. Flow nets will yield the geometry of the groundwater surface and the direction of groundwater flow, but will not determine the volume of impact from wells.

Analytical methods are derived from Darcy's Law and the Law of Conservation. Analytical methods require restrictive assumptions, known as Dupuit assumptions (listed in Table 2-1). These methods were developed as analogies to heat flow theory and as such are well founded in higher mathematics and physics.

Theis in 1935 developed a formula to predict drawdown from a pumping well, defining radial groundwater flow to a pumping well. The formula is commonly expressed as:

$$h_o - h = \frac{Q}{4\pi T}\int \frac{e^{-u}du}{u}$$

where

$$u = \frac{r^2 S}{4Tt}$$

where Q = discharge
h = drawdown,
S = storage coefficient,
T = transmissivity,
t = duration of pumping,
r = radius from the pumping well.

The equation is commonly solved graphically. In 1941, Theis expanded his groundwater flow formula to solve problems related to wells intercepting streamflow from groundwater pumpage. The stream depletion is shown by the following equation:

$$depletion = \frac{2}{\pi}\int^{\pi/2} e^{-1.87\frac{a^2 S}{t*T}\sec^2 u}du$$

where a = distance from stream,
S = storage coefficient,

the solution or adapted it to various hydrologic cases. The most common adaptation is the Jenkins equation, 1968. Jenkins developed a graphical solution to the Theis equation that yields the following formula:

$$depletion = \frac{t}{sdf} = \frac{t * T}{a^2 * S}$$

where: sdf = Jenkins'stream depletion factor
a = distance from stream,
S = storage coefficient,
T = transmissivity,
t = duration of pumping

These methods can predict the depletion of streamflow from wells, at what time during pumping a well impact a stream, and solve for threshold values such as 50% depletion. However, these methods are restricted to a series of assumptions that serve to simplify the natural system. If some of the assumptions are not met, these tests fail.

Numerical methods are algebraic approximations of analytical solutions. The solutions to these algebraic approximations are carried out simultaneously by digital computers. Numerical solutions are not bound by the same restrictive assumptions as analytical methods. However, to provide consistent results, the numerical solutions require a great deal of high quality data.

The study area for a numerical model is divided into grids or nodes. The numerical solutions are solved at each node in a study area, but cannot derive site or well specific solutions. The algebraic approximations are commonly solved by iterative methods at each node. The iterative method solves the simultaneous equation at each node and proceeds through the study grid in an orderly fashion. At the node (i,j) in a study grid, the algebraic approximation for two dimensional groundwater flow is:

$$h_{i-1,j}+h_{i+1,j}+h_{i,j-1}+h_{i+j+1}-4h_{i,j}=0$$

where: h = head at each node surrounding (i,j).

This is for steady state and approximates the Laplace equation for two-dimensional flow. The solution to the equation at node (i,j) is then:

$$h_{i,j}=\frac{h_{i-1,j}+h_{i+1,j}+h_{i,j-1}+h_{i,j+1}}{4}$$

The solution is the average value of head computed from the nearest neighbors in the node array.

A complete discussion of numerical methods is beyond the scope of this report. However, the text by Wang and Anderson, 1982, provides a complete introduction to the subject.

This appendix describes in more detail the technical methods used by the Arizona Department of Water Resources (DWR) to determine the direction of streamflow and the delineation of the accounting surface. These two determinations utilize numerical models such as the method of least-squares and linear interpolation of stream geometry.

B.1 DIRECTION OF THE STREAM

A determination of the direction of streamflow is necessary in order to follow through with a technical determination of the Court's Opinion. An important consideration in this determination is that this direction is required for comparison to the direction of subterranean flow. From a cursory glance, an analysis of the stream's direction seems to be a simple matter of obtaining the streamflow direction at a discrete point. But, although the direction of the stream can be determined in this fashion, it does not mean that the flow direction thus derived is readily comparable to that of the subterranean water. Typically, subterranean water exists and flows though a volume of strata that is at least an order of magnitude larger than the volume of space occupied by the stream. In the San Pedro River for example, the area of the basin fill which contains subterranean water is approximately 2,300 square miles while the dynamic channel of the streams only occupies about nineteen square miles. Additionally, the depth of subterranean water is not measured in feet, as for surface streams, but in hundreds of feet.

In contrast to the lingering, seemingly deliberate flow of the subterranean water, the stream is responsive to more subtle forces, appearing to be oscillating wildly in comparison to the meandering of the subterranean water. To adequately compare the by eye but a more precise method is required. Since the coordinates of the stream are essentially statistical data, a functional approximation of stream direction can be made. One simple functional approximation often used to smooth statistical data, such as the coordinates of a stream, is called the method of least-squares.

The use of the method of least-squares in the case of defining streamflow direction is based on some underlying concepts. One of these concepts is that stream coordinates with a high degree of correlation define a straight reach of the stream. Essentially, this would be the flow direction of this particular reach based upon watershed-scale land features. These large scale features would produce a more general stream direction, such as occurs for subterranean flow, were the course of the stream not altered by smaller surface features. A second concept in the use of the least-squares approach is that the end of a straight reach is defined where the correlation of the coordinates is no longer high. When the correlation drops, a new analysis will be required to find the direction of the next stream reach. The normalized flow direction could then be utilized in the comparison of flow direction between the subterranean system and the stream.

To determine the correlation of the stream coordinates, a variety of coordinate subsets can be analyzed (coordinates of the midpoint of the banks are readily computed through the use of DWR's Geographic Information System). An analysis of two successive coordinates will always have a correlation coefficient (*r*) equal to one (the highest possible correlation) since the function of two points always describe a straight line. Therefore analysis of three consecutive points is the minimum number for a useful analysis of correlation. However, the spacing of these data points along the dynamic channel could have a profound impact upon the maximum number of points which need to be analyzed and upon the ability of the least-squares function to filter noise. A very close spacing of points, say every foot along the stream, would not reduce the noise of any land feature larger than one foot. Since the analysis is attempting to filter the noise cause by items such as rock outcrops and material which is inconsistent with the rest of the alluvial material, a coordinate point spacing of at least several hundred yards should be a starting point. At this point, a sensitivity analysis can then be made of the then the point spacing is too sensitive for that particular stream. The point spacing should be increased to reduce the number of data points which will correlate in order to adequately filter the noise. If the spacing yields results that do not correlate for five or fewer points on average, the data is too insensitive and the point spacing needs to be decreased to obtain a correlation between more points.

The equation used to calculate the coefficient of correlation r for the least squares method is:

$$r=\frac{n\Sigma(x_i y_i)-(\Sigma x_i)(\Sigma y_i)}{\sqrt{[n\Sigma x_i^2-(\Sigma x_i)^2][n\Sigma y_i^2-(\Sigma y_i)^2]}}$$

Where r = correlation coefficient

x = x coordinate of discrete point i

y = y coordinate of discrete point i

n = number of discrete points evaluated

DWR chose to use a minimum absolute r of 0.9 for the example analysis presented in this report. Generally, an r value of 0.85 or greater describes a good fit of a straight line to the data points.

As stated earlier, when the correlation coefficient of a set of data points drops below a certain value, 0.9 in this case, it indicates the end of one stream reach whose discrete points correlate highly to a straight line defining the direction of flow of that stream reach. This drop in r also indicates the beginning of another reach of stream having a different flow direction. One caution in this approach is that a sharp drop in the value of r or a change in the value of r from positive to negative or negative to positive indicates that an inflection of the stream has been encountered. The inflection, when one of the ordinate values alternately increases and decreases in magnitude, causes the absolute value of r to be less than 0.9. A straight line through this that the magnitude of the coordinates does not alternately increase and decrease the correlation coefficient of a line passing through the inflection may remain high. For example, Table B-1 shows the standard and rotated coordinates and corresponding *r* value for a stream reach with an inflection as shown in Figure B-1. Note how the rotated x coordinates does not increase then decrease in magnitude as do the standard x coordinates.

TABLE B-1
STANDARD V. ALTERNATIVE COORDINATES FOR INFLECTIONS IN STREAM DIRECTION

STANDARD COORDINATES r = 0.725		ROTATED COORDINATES r = -0.941	
X COORDINATE	Y COORDINATE	X COORDINATE	Y COORDINATE
359	92	359	92
479	245	552	116
537	436	729	210
529	631	861	353
507	829	985	509

To illustrate the method of least squares, consider the stream section shown in Figure B-2A. The centerline of the dynamic channel can be described by data points located about every two hundred yards along its length. The centerline of the stream is shown as a line through these discrete points as shown in Figure B-2B. A sensitivity analysis shows that the correlation coefficient remains above 0.9 of an average of over seven points, making up four line segments (each separate line segment must share a point with another line segment, making the number of analyzed points 29 but only 26 points define this stream reach). Therefore, the point spacing appears to be good. To find the beginning and ending coordinates for the line segment, conduct an analysis of the *r* values for a moving five point least-squares calculation (i.e. analyze points 1 through 5, then points 2 through 6, etc.). A moving five point analysis is conducted

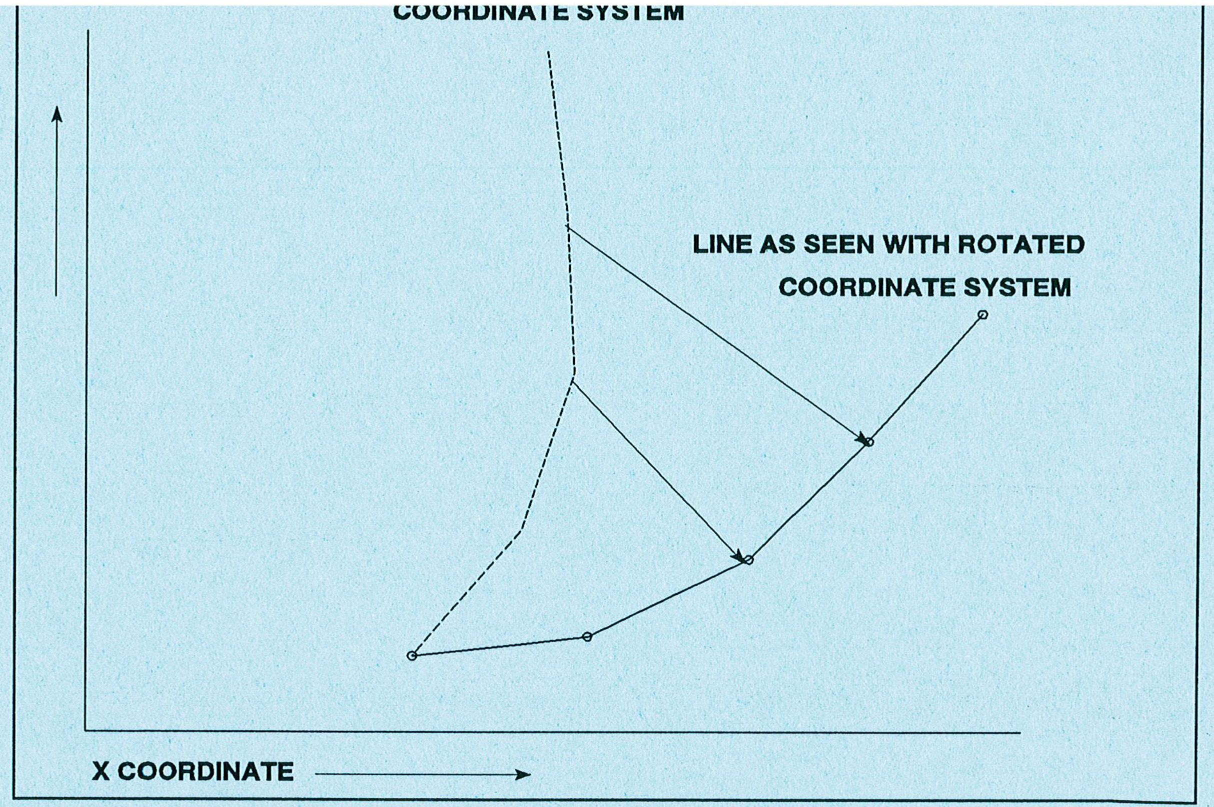


Figure B-1. Example of how the perception from a different coordinate system can make a set of coordinates which are alternately increasing and decreasing in magnitude yield an accurate analysis through the method of least-squares.

sensitivity analysis. Table B-2 shows that the *r* value for points 1 through 5, 2 through 6, 3 through 7, and 4 through 8 remains above the minimum 0.9. However, the analysis shows that *r* for points 5 through 9 drops below the minimum value. This indicates that the straight line segment with a good fit will run from point 1 through 8. As a final check, an eight point analysis is made for points 1 through 8 which shows an *r* value of 0.969, which still meets the criteria.

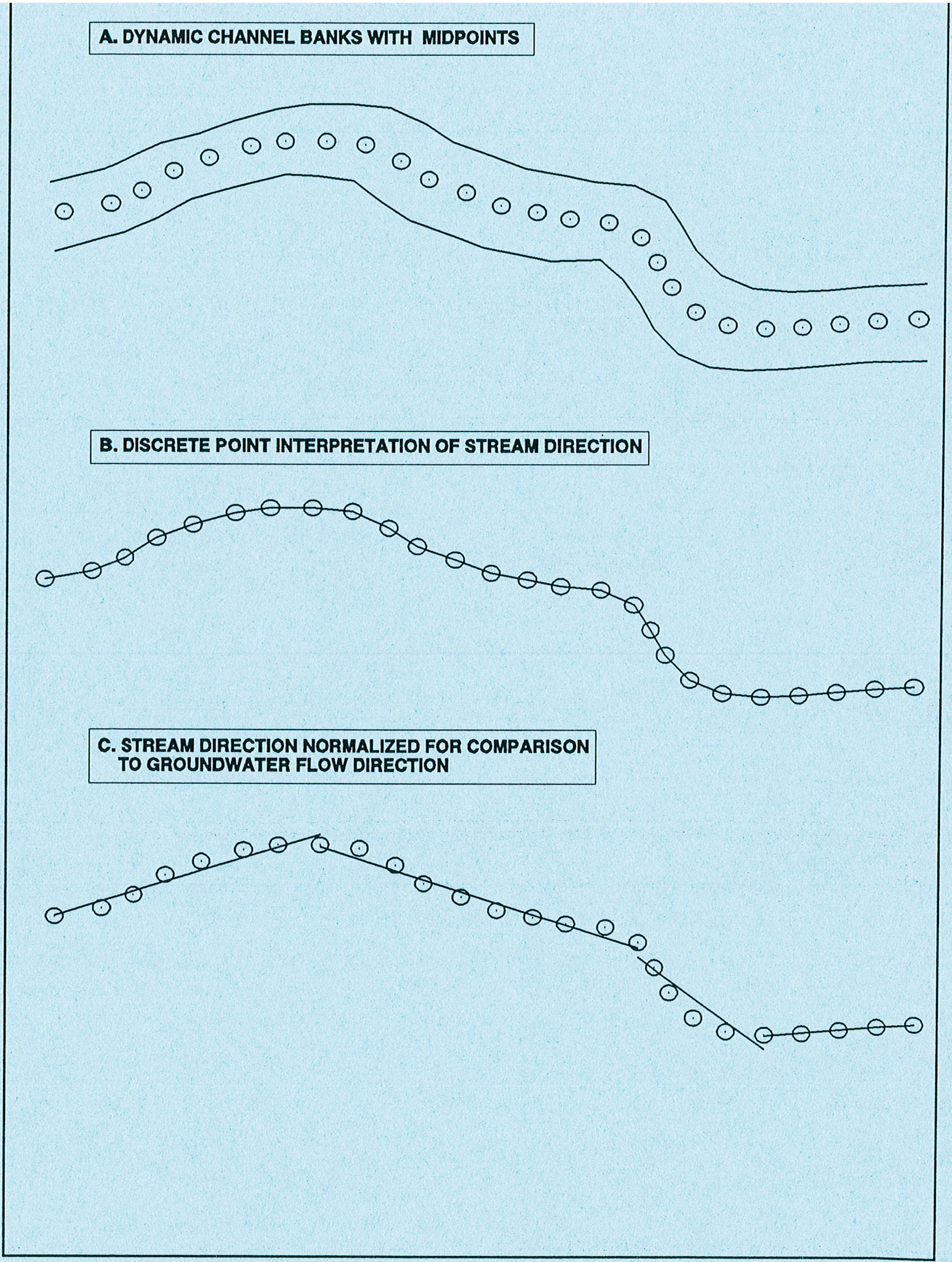


Figure B-2. Utilizing information about the center point of the Dynamic Channel to

CORRELATION COEFFICIENT FOR MOVING FIVE POINT LEAST-SQUARES ANALYSIS

Points Used in Analysis			Correlation Coefficient
1	through	5	0.979
2	through	6	0.990
3	through	7	0.972
4	through	8	0.935
5	through	9	0.724

The final step in computing the direction of streamflow for this reach is to derive the equation of the line which best fits through these data points. The general equation of the line is:

$$y=mx+b$$

where y = y coordinate for the discrete point i

x = x coordinate for the discrete point i

$$m=\frac{n\Sigma(x_i y_i)-(\Sigma x_i)(\Sigma y_i)}{n\Sigma x_i^2-(\Sigma x_i)^2}$$

$$b=\bar{y}-m\bar{x}$$

$$\bar{x}=\frac{\Sigma x_i}{n} \qquad \bar{y}=\frac{\Sigma y_i}{n}$$

For this illustrative example, the equation which defines the first direction line is:

$$y=17.47+x(0.35)$$

The accounting surface defines the surface of the subterranean water which is more closely related to the stream than the surrounding aquifers. The determination of the relationship between the subterranean waters and the stream through the use of subterranean water table contours have been previously discussed. Construction of the accounting surface boundaries between contour lines will require some interpolation for an accurate representation. For example, Figure B-3A shows a stream reach with subterranean water level contours spaced far apart due to the quality and quantity of well data. Finding the 45 degree tangent line to the contour and drawing a straight line between these points creates an accounting surface that is obviously incorrect. Instead, since the stream direction lines are at the same scale of observation as the subterranean flow, the geometry can be used to define the geometry of the river aquifer, and therefore the accounting surface. The distance out to the 45 degree tangent intersect can be plotted from the dynamic channel center at an angle which is perpendicular to the flow direction lines. At the point where two flow lines meet the average of the perpendicular angles is used to plot the distance out to the accounting surface (Figure B-3B). If the distance from the channel center to the tangent on the contour line is not equal for the two contours, the distance of the points between can be calculated by linear interpolation.

$$x_n = x_i + ((x_i - x_n) * \frac{DX_i}{\Sigma DX_n})$$

where i = a discrete point

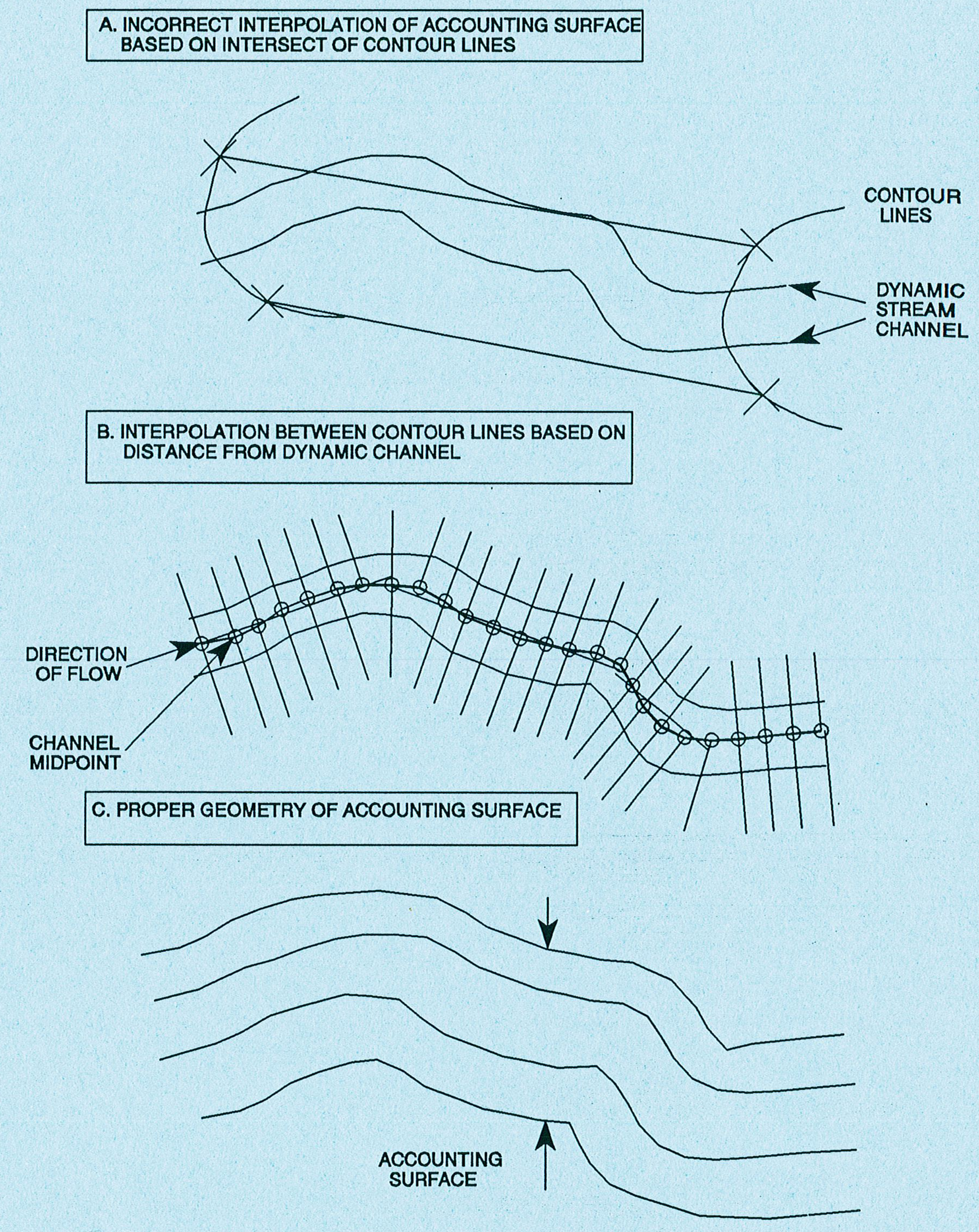
n = total number of points

x_i = distance from center of dynamic channel to 45 degree tangent on first contour

x_n = distance from center of dynamic channel to 45 degree tangent on second contour

DX = distance between discrete points

DXn = total of the distances between discrete points


A. INCORRECT INTERPOLATION OF ACCOUNTING SURFACE BASED ON INTERSECT OF CONTOUR LINES
CONTOUR LINES
DYNAMIC STREAM CHANNEL
B. INTERPOLATION BETWEEN CONTOUR LINES BASED ON DISTANCE FROM DYNAMIC CHANNEL
DIRECTION OF FLOW
CHANNEL MIDPOINT
C. PROPER GEOMETRY OF ACCOUNTING SURFACE
ACCOUNTING SURFACE

straight line between the points would still not approximate the river aquifer. These points as established now allow for an accurate interpolation.

In the future as DWR develops computer modeling capabilities for the modified flow net analysis the accounting surface will be potentially drawn directly on a three dimensional model of the groundwater surface rather than going through the contouring and interpolation procedure described in this appendices.

The following series of tables provides a list of well data used in delineating the accounting surface for the examples provided in Chapter 5. As previously stated, this information would be inadequate for an actual delineation of an accounting surface due to the fact that the data was collected at many different times and during different years. It is therefore not representative of a water table at one instant in time. Deep wells within confined layers were discounted from the analysis, wells that are over 500 feet deep listed in Tables C-1 and C-2 are wells that were located some distance away from known confined zones, as are wells that are over 250 feet listed in Tables C-3 and C-4. Wells from DWR's well registration database (Wells 55) were only locatable within a 10 or 40 acre size area and were therefore only used to fill in the gaps in the data from the Groundwater Site Inventory (GWSI) database.

TABLE C-1
REGISTERED WELLS USED FOR ALLUVIAL STREAM WITH CONFINED LAYER EXAMPLE

WELL REGISTRATION # (55 #)	LOCAL ID	WATER LEVEL ELEV (FT)	WELL DEPTH (FT)
624643	D-08-17 29ACA	2377	NO DATA
624625	D-08-17 29DDA	2367	100
600287	D-08-17 33AC	2363	63
530003	D-08-17 33BDB	2365	120
530004	D-08-17 33BDB	2373	100
806352	D-08-17 33DB	2431	110
604260	D-08-17 33DBC	2391	62
604261	D-08-17 33DBC	2391	210
619152	D-08-17 33DC	2421	60
607862	D-09-17 04AA	2392	150

WELL REGISTRATION # (55 #)	LOCAL ID	WATER LEVEL ELEV (FT)	WELL DEPTH (FT)
607867	D-09-17 04ADC	2429	150
607865	D-09-17 04ADC	2429	130
624635	D-09-17 04CDA	2412	16
624639	D-09-17 09DBA	2450	130
624637	D-09-17 10CDC	2448	400
607683	D-09-17 10DCB	2395	453
529971	D-09-17 14CAB	2471	65
624626	D-09-17 14CDC	2478	NO DATA
624635	D-09-17 15ABD	2464	53
529968	D-09-17 15BBD	2435	65
537377	D-09-17 16ADD	2410	260
537378	D-09-17 22DBB	2670	130
529969	D-09-17 23BCA	1500	63
537230	D-09-17 23BCB	2359	176
537231	D-09-17 23BCB	2281	225
537227	D-09-17 23BCD	2480	50
624814	D-09-17 23BCD	2488	80
537228	D-09-17 23BCD	2395	172
537229	D-09-17 23BCD	2346	237
624628	D-09-17 24CDC	2504	100
537379	D-09-17 28DCB	2830	85

TABLE C-2
GWSI WELLS USED FOR ALLUVIAL STREAM WITH CONFINED LAYER EXAMPLE

SITE ID	LOCAL ID	WATER LEVEL ELEV (FT)	UTM EAST	UTM NORTH	WELL DEPTH (FT)
324212110371501	D-08-17 29DDA	2372	535539	418273	100
324256110382601	D-08-17 30AAB	2366	533686	419622	295
324231110383101	D-08-17 30ACD	2365	533558	418851	277
324135110390301	D-08-17 31CBA	2470	532731	417124	400
324143110371601	D-08-17 32ADD	2381	535516	417380	100
324130110372401	D-08-17 32DAC	2368	535309	416979	62
324144110364401	D-08-17 33BDD	2396	536349	417414	70
324130110362901	D-08-17 33DBD	2404	536741	416984	180
324141110332201	D-08-17 36ACD	2725	541609	417342	425
324032110343101	D-09-17 02DCB	2445	539821	415210	1025
324058110361201	D-09-17 04ADA	2400	537188	416000	NO DATA
324025110364301	D-09-17 04CDD	2420	536384	414981	36
323955110362601	D-09-17 09DBA	2445	536830	414059	55
323938110353301	D-09-17 10DCB	2439	538213	413541	85
323913110351801	D-09-17 15ADB	2455	538606	412773	53
323859110350901	D-09-17 15DAA	2470	538842	412342	NO DATA
323859110352701	D-09-17 15DBA1	2478	538374	412341	64
323858110352601	D-09-17 15DBA2	2473	538400	412310	35
323756110332901	D-09-17 24DCB1	2497	541456	410413	82

REGISTERED WELLS USED FOR ALLUVIAL VALLEY EXAMPLE

REGISTERED WELL # (55 #)	LOCAL ID	WATER LEVEL ELEV (FT)	WELL DEPTH (FT)
519933	D-23-22 33AAA	4172	85
642535	D-23-22 33AAA	4181	90
505414	D-23-22 33CDC	4211	160
607868	D-23-22 33CDC	4204	84
536492	D-23-22 33DCD	4202	100
637816	D-23-22 33DCD	4204	150
648448	D-23-22 33DCD	4206	260
806319	D-23-22 33DCD	4214	100
605144	D-23-22 34AAC	4200	200
605145	D-23-22 34AAC	4203	120
513254	D-23-22 34CAC	4220	152
60952	D-23-22 35ABD	4171	250
516198	D-23-22 28AAB	4195	80
538145	D-23-22 28AAD	4197	125
637785	D-23-22 28AAD	4175	120
611665	D-23-22 28ACB	4189	220
85521	D-23-22 28ADD	4185	61
528560	D-23-22 28ADD	4187	120
517401	D-23-22 28BAB	4152	250
629911	D-23-22 28BAD	4201	76
642953	D-23-22 28BAD	4181	100
601630	D-23-22 28BBB	4172	123
618732	D-23-22 28BBC	4180	250
617973	D-23-22 28BCA	4190	80

REGISTERED WELL # (55 #)	LOCAL ID	WATER LEVEL ELEV (FT)	WELL DEPTH (FT)
801773	D-23-22 28BCA	4185	120
519581	D-23-22 28BCC	4201	132
632921	D-23-22 28BDA	4184	86
650839	D-23-22 28BDA	4182	106
507397	D-23-22 28CCD	4174	130
507396	D-23-22 28CDC	4180	110
607965	D-23-22 28DAB	4180	205
512396	D-23-22 28DAD	4188	100
605033	D-23-22 28DBA	4183	95
605034	D-23-22 28DBA	4183	107
641386	D-23-22 28DBA	4183	105
501981	D-23-22 28DBB	4184	150
611177	D-23-22 28DBB	4185	150
602281	D-23-22 28DBC	4179	100
637198	D-23-22 28DBC	4179	45
643449	D-23-22 28DBC	4187	82
629824	D-23-22 28DBD	4189	115
516666	D-23-22 28DCA	4173	100
642515	D-23-22 28DCA	4138	150
611176	D-23-22 28DCB	4185	105
605101	D-23-22 28DCC	4199	150
601558	D-23-22 28DCD	4195	118
531603	D-23-22 28DDA	4155	99
647426	D-23-22 28DDB	4178	100
610245	D-23-22 27DBA	4191	132
610246	D-23-22 27DBA	4198	200

REGISTERED WELL # (55 #)	LOCAL ID	WATER LEVEL ELEV (FT)	WELL DEPTH (FT)
512567	D-23-22 27DCB	4187	200
513863	D-24-22 04ABB	4190	100
602110	D-24-22 04BAA	4192	150
630372	D-24-22 04BAA	4190	90
630521	D-24-22 04BBA	4203	31
637829	D-24-22 04BBA	4198	40
511139	D-24-22 04BBB	4185	100
612901	D-24-22 04BBD	4202	123
633902	D-24-22 04BBD	4202	123
633165	D-24-22 04BBD	4206	90
620384	D-24-22 05AAA	4204	65
633163	D-24-22 05AAA	4204	100
87173	D-24-22 05AAB	4199	103
600298	D-24-22 05AAB	4207	210
642040	D-24-22 05BBA	4197	200
84966	D-24-22 05BBA	4191	180
613446	D-24-22 05BBB	4206	180
644205	D-24-22 05BBD	4211	160
631439	D-24-22 05BCD	4221	168
633164	D-24-22 05BCD	4216	160
607007	D-24-22 05CCC	4205	115
627431	D-24-22 05CCC	4210	110
600299	D-24-22 07ADA	4241	186
600646	D-24-22 07BAD	4215	220
642072	D-24-22 08ADA	4202	200
86096	D-24-22 08BAA	4230	230
642037	D-24-22 08BAA	4183	230

GWSI WELLS USED FOR ALLUVIAL VALLEY EXAMPLE

SITE ID	LOCAL ID	WATER LEVEL ELEV (FT)	UTM EAST	UTM NORTH	WELL DEPTH (FT)
312501110074701	D-23-22 20ACC	4194	582721	275954	45
312454110073701	D-23-22 20DBA	4189	582987	275740	NO DATA
312442110073101	D-23-22 20DDB	4201	583148	275372	460
312515110063701	D-23-22 21ABD3	4031	584566	276400	209
312438110065401	D-23-22 21CDA	4180	584126	275257	100
312449110055901	D-23-22 22CAC	4150	585576	275607	NO DATA
312434110040101	D-23-22 24CCD	4200	588696	275171	250
312421110041001	D-23-22 25BBC	4202	588461	274769	312
312406110055201	D-23-22 27CAA2	4182	585798	274224	NO DATA
312421110064501	D-23-22 28ABC	4189	584316	274673	220
312429110065301	D-23-22 28BAA1	4180	584155	274980	156
312429110065401	D-23-22 28BAA2	4176	584128	274980	85
312429110065501	D-23-22 28BAA3	4180	584102	274980	150
312429110065601	D-23-22 28BAA4	4179	584076	274979	116
312420110065001	D-23-22 28BAD	4177	584236	274704	103.5
312415110065101	D-23-22 28BDA1	4193	584211	274549	86.4
312415110065001	D-23-22 28BDA2	4192	584238	274550	125
312354110070101	D-23-22 28CAC	4214	583952	273901	96
312340110061901	D-23-22 28DCC	4203	585065	273479	150
312350110063001	D-23-22 28DDB	4169	584772	273784	101
312417110074801	D-23-22 29ACB	4207	582705	274599	460
312403110072401	D-23-22 29DAA	4198	583395	274235	563
312357110073901	D-23-22 29DBD	4202	582948	273985	460
312304110085601	D-23-22 31CAD1	4218	580927	272337	700
312303110085601	D-23-22 31CAD2	4209	580927	272307	NO DATA

SITE ID	LOCAL ID	WATER LEVEL ELEV (FT)	UTM EAST	UTM NORTH	WELL DEPTH (FT)
312249110072101	D-23-22 32DDD2	4200	583440	271895	201
312336110063001	D-23-22 33AAB	4183	584775	273353	80
312322110063101	D-23-22 33ADB	4189	584753	272922	90
312329110070101	D-23-22 33BAC	4207	583958	273131	26
312336110071001	D-23-22 33BBA	4192	583719	273345	NO DATA
312312110065801	D-23-22 33CAC	4215	583964	272423	NO DATA
312304110070701	D-23-22 33CBD	4211	583806	272360	234
312251110065201	D-23-22 33CDD	4199	584206	271963	NO DATA
312251110064501	D-23-22 33DCC2	4201	584390	271965	200
312251110063801	D-23-22 33DCD1	4210	584575	271966	50
312250110063901	D-23-22 33DCD2	4211	584549	271935	91.5
312249110063801	D-23-22 33DCD3	4204	584576	271904	NO DATA
312300110061901	D-23-22 33DDA	4191	585075	272247	100
312258110063001	D-23-22 33DDB	4198	584785	272183	101
312329110053101	D-23-22 34AAC	4206	586336	273150	120
312330110053601	D-23-22 34ABD	4208	586203	273180	170
312340110055301	D-23-22 34BAA	4211	585752	273484	NO DATA
312304110060701	D-23-22 34CBD2	4214	585391	272373	165
312250110060101	D-23-22 34CDC1	4230	585553	271943	NO DATA
312250110055901	D-23-22 34CDC2	4220	585606	271882	180
312739110031201	D-23-23 06BCC	4152	589940	280878	1000
312448110010801	D-23-23 21CBC	4207	593260	275642	NO DATA
312323110020901	D-23-23 32BCB	4225	591672	273011	270
312315110021201	D-23-23 32BCC	4204	591594	272887	270
312153110031001	D-24-22 01ACC	4202	590085	270226	NO DATA
312220110033501	D-24-22 01DBA	4207	589417	271052	222

SITE ID	LOCAL ID	WATER LEVEL ELEV (FT)	UTM EAST	UTM NORTH	WELL DEPTH (FT)
312246110065601	D-24-22 04BAB1	4210	584101	271808	NO DATA
312243110070101	D-24-22 04BAB2	4213	583970	271715	70
312222110071601	D-24-22 04BCC	4217	583579	271065	NO DATA
312205110070901	D-24-22 04CCA	4214	583768	270543	178
312159110064501	D-24-22 04DCC	4235	584403	270364	50
312243110072901	D-24-22 05AAB	4219	583230	271709	NO DATA
312230110073901	D-24-22 05ACA	4226	582969	271307	210
312159110081801	D-24-22 05CCC	4230	581946	270344	325
312141110072501	D-24-22 08ADA1	4235	583351	269801	110
312153110081701	D-24-22 08BBB	4235	581974	270160	250

TABLE C-5
REGISTERED WELLS USED FOR BEDROCK CANYON STREAMS EXAMPLE

REGISTRATION # (55 #)	LOCAL ID	DEPTH TO WATER (FT)	WELL DEPTH (FT)
612948	D-06-17 26C	12	30
618440	D-06-17 26C	14	29
618441	D-06-17 26C	12	28
603731	D-06-17 26CCB	19	42
637284	D-06-17 34A	18	20
528476	D-06-17 34AAA	15	54
648741	D-06-17 34ACA	12	35
648742	D-06-17 34ACA	3	25
528178	D-06-17 34ACC	15	62
522863	D-06-17 34CAD	22	54
529934	D-06-17 34CAD	27	54
603062	D-06-17 34CCA	12	32
603063	D-06-17 34CCA	22	38
637752	D-06-17 34CCA	22	39
623331	D-06-17 34CCD	20	46

GWSI WELLS USED FOR BEDROCK CANYON STREAM EXAMPLE

SITE ID	LOCAL ID	WATER LEVEL ELEV (FT)	UTM EAST	UTM NORTH
325338110341301	D-06-17 23DAD	2589	540192	439415
325324110341701	D-06-17 23DDD	2573	540089	438984
325346110340301	D-06-17 24CBA2	2589	540450	439662
325308110343201	D-06-17 26ACA	2536	539702	438489
325302110344701	D-06-17 26BDA1	2524	539313	438303
325302110344901	D-06-17 26BDA2	2530	539261	438303
325245110350201	D-06-17 26CBD	2512	538925	437778
325243110345701	D-06-17 26CCA	2509	539055	437717
325238110351001	D-06-17 26CCB	2508	538718	437562
325224110352301	D-06-17 34AAB	2465	538382	437129
325215110353701	D-06-17 34ACB	2505	538019	436851
325147110360301	D-06-17 34CCA	2525	537347	435986

PLATE 1

TECHNICAL ASSESSMENT OF ARIZONA SUPREME COURT
INTERLOCUTORY APPEAL ISSUE NO.2 OPINION

Arizona Department of Water Resources
Adjudications Division

December 15, 1993

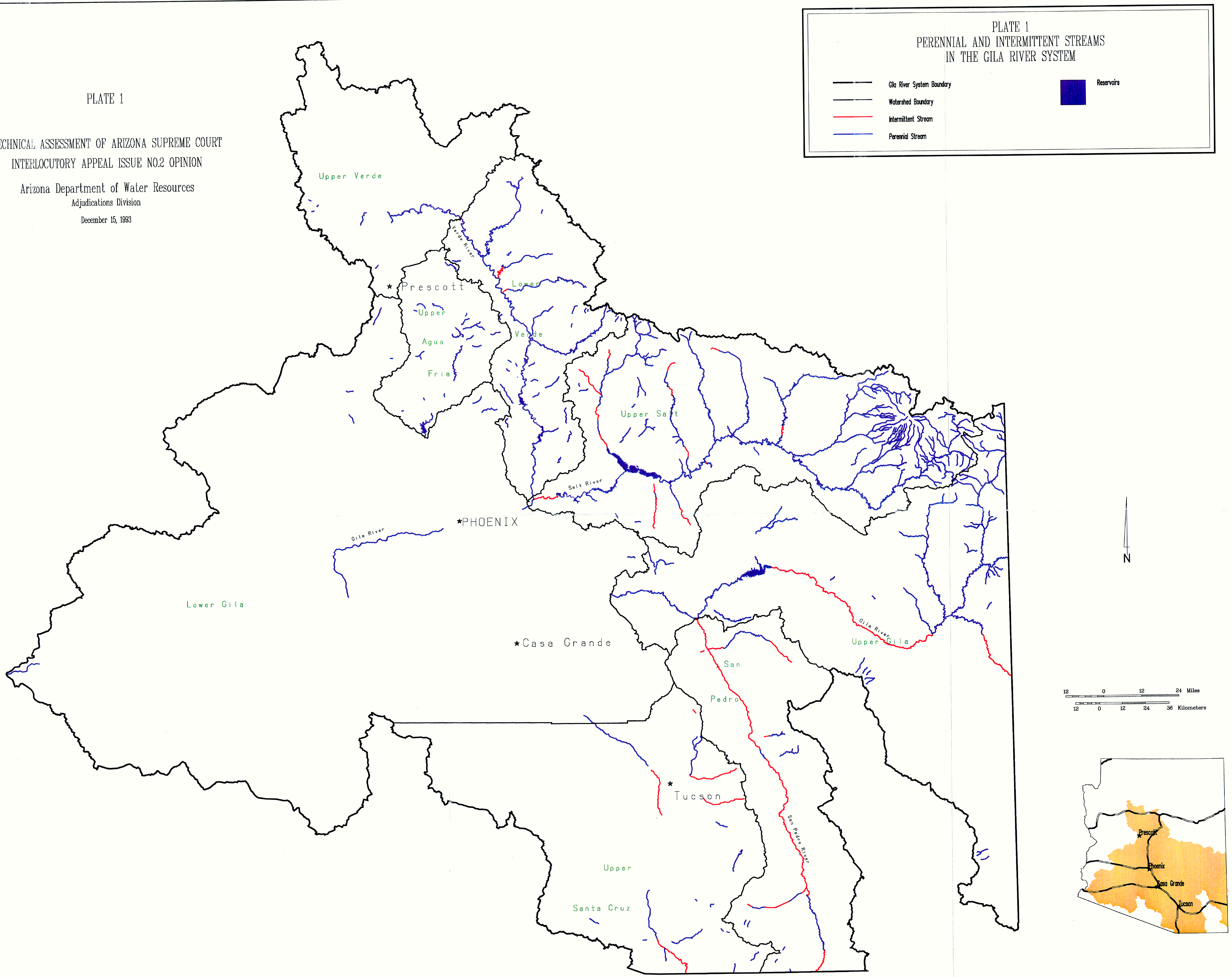


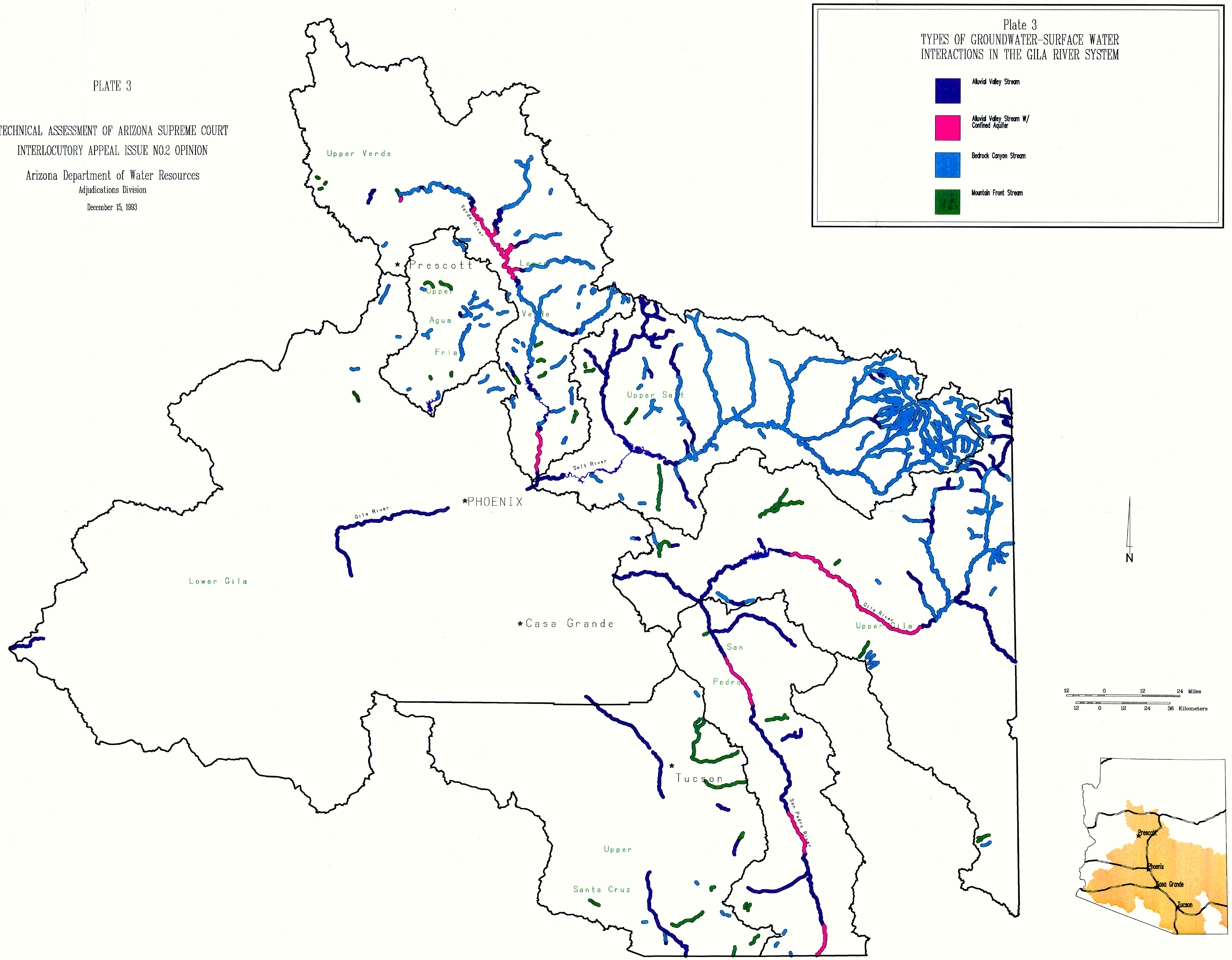

PLATE 2
TECHNICAL ASSESSMENT OF ARIZONA SUPREME COURT
INTERLOCUTORY APPEAL ISSUE NO.2 OPINION
Arizona Department of Water Resources
Adjudications Division
December 15, 1993
PLATE 2
AQUIFER TYPES WITHIN THE GILA RIVER SYSTEM
Gila River System Boundary
Watershed Boundary
Reservoirs
Younger Alluvium
Younger Alluvium Dominated by Effluent
Tributary Unconsolidated Aquifer
Confined Aquifers Underlying Tributary Aquifer
Tributary Consolidated Aquifer
Non-tributary Aquifer
Non-tributary Hardrock
N
12 0 12 24 Miles
12 0 12 24 36 Kilometers
Prescott
PHOENIX
Casa Grande
Tucson

PLATE 3

TECHNICAL ASSESSMENT OF ARIZONA SUPREME COURT
INTERLOCUTORY APPEAL ISSUE NO.2 OPINION

Arizona Department of Water Resources
Adjudications Division

December 15, 1993



ARIZONA DEPARTMENT OF WATER RESOURCES
ADJUDICATIONS DIVISION

TO: **Interested Parties**

FROM: **Charles Cullom**

DATE: **June 6, 1994**

SUBJECT: **Channel and Riparian Vegetation Changes along the San Pedro River**

DWR has revised the preliminary analysis documenting channel change and riparian vegetation changes along the San Pedro River. The revision corrects computation errors included in the original April 29, 1994 report. This report replaces the report of April 29, 1994.

The values reported here are based on aerial photography and have not been field checked. The report serves to the illustrate the general magnitude of changes along the river. If you have questions regarding the work here or would like to examine the photography, please contact me at 542-1520.

DWR analysis of San Pedro River channel changes from 1935 to 1990.

DWR analyzed the historical aerial photography data base of selected areas of the San Pedro River watershed to document channel change. Channel change was of two types, channel shift (avulsion) and channel narrowing. The channel shifts range from 0 to approximately 1,200 feet as shown in the following table. Channel narrowing ranges from -170 (widening) to 970 feet. The channel was defined for this study as the "sandy wash" described by Dr. Montgomery. The following tables describe the results of the analysis.

The assessment was conducted by locating identical physical or cultural points on the east and west side of the San Pedro River on the 1990 and 1935 photography. A transect line was then drawn to connect the points on each photo. The distance from each point to the "sandy wash" as well as the width of the wash was measured. The difference in width of the "sandy wash" defines narrowing and is rounded to the nearest 10 ft. The shift is defined by the maximum difference in distance from the point to the wash on each side of the wash. The shift is the absolute value of the maximum distance and is rounded to the nearest 100 ft.

Photo 1 - Hereford SW (Mexico to Palominas)[1]		
Transect	Narrowing	Shift
1a	-170	500

Photo 2 - Hereford (Palominas to Lewis Spring)[1]		
Transect	Narrowing	Shift
2a	210	500
2b	310	700
2c	480	300
2d	100	100

Photo 3 - Lewis Spring (Lewis Spring to Charleston)[1]		
Transect	Narrowing	Shift
3a	170	400
3b	440	400
3c	400	500
3d	130	100

Photo 4 - Fairbank (Charleston to Fairbank)[1]		
Transect	Narrowing	Shift
4a	240	200
4b	340	600

Photo 5 - Land (Fairbank to St. David)[1]		
Transect	Narrowing	Shift
5a	100	100
5b	630	500
5c	70	1,000

Photo 6 - Benson (St. David to Pomerene)[1]		
Transect	Narrowing	Shift
6a	130	200
6b	100	1,200
6c	0	700
6d	300	500

Photo 7 - Galleta Flats East (Pomerene to Narrows)[1]		
Transect	Narrowing	Shift
7a	370	700
7b	200	500
7c	100	100
7d	130	100

Photo 8 - Wildhorse Mnt[1]		
Transect	Narrowing	Shift
8a	970	900
8b	400	400
8c	200	300

Photo 9 - Clark Ranch (Mammoth area)[1]		
Transect	Narrowing	Shift
9a	500	400
9b	800	500
9c	400	600

[1] all values in feet

Paul L. Sale Property Channel Shift approximately 950 feet as determined from previous mapping and communication with the property owner.

DWR analysis of change in riparian habitat along the San Pedro River from 1935 to 1990.

DWR analyzed the historical aerial photography data base of selected areas of the San Pedro River watershed to document change in the extent of riparian vegetation. The change in riparian vegetation along the San Pedro River channel varies widely across the watershed. The magnitude of change is shown in feet along a study transect. The changes are summarized in the following tables.

DWR used the same general methods as outlined for channel changes. The amount of riparian change is defined as the sum of riparian change on the west and east sides of the wash. The riparian change was calculated by subtracting the riparian distance on the 1990 photos from the riparian distance on the 1935 photos. All values are rounded to the nearest 100 feet.

Photo 1 - Hereford SW (Mexico to Palominas)[1]	
Transect	Riparian Change
1a	+100 ft

Photo 2 - Hereford (Palominas to Lewis Spring)[1]	
Transect	Riparian Change
2a	+500 ft
2b	-300 ft
2c	no change 0
2d	no change 0

Photo 3 - Lewis Spring (Lewis Spring to Charleston)[1]	
Transect	Riparian Change
3a	-300 ft
3b	+200 ft
3c	-100 ft
3d	-200 ft

Photo 4 - Fairbank (Charleston to Fairbank)[1]	
Transect	Riparian Change
4a	-100 ft
4b	-500 ft

Photo 5 - Land (Fairbank to St. David)[1]	
Transect	Riparian Change
5a	-1900 ft
5b	no change 0 ft
5c	-200 ft

Photo 6 - Benson (St. David to Pomerene)[1]	
Transect	Riparian Change
6a	+800 ft
6b	+800 ft
6c	+200 ft
6d	-200 ft

Photo 7 - Galleta Flats East (Pomerene to Narrows)[1]	
Transect	Riparian Change
7a	no change 0 ft
7b	+600 ft
7c	-300 ft
7d	-500 ft

Photo 8 - Wildhorse Mnt[1]	
Transect	Riparian Change
8a	+3100 ft
8b	+1800 ft
8c	+1900 ft

Photo 9 - Clark Ranch (Mammoth area)[1]	
Transect	Riparian Change
9a	-500 ft
9b	+700 ft
9c	-500 ft

Copy of the foregoing report
mailed this _____ day of
June, 1994, to all persons
on the Court approved mailing
list dated June 6, 1994

____

IN THE SUPERIOR COURT OF THE STATE OF ARIZONA

IN AND FOR THE COUNTY OF MARICOPA

In re the general adjudication of)
all rights to use water in the) W-1, W-2, W-3, W-4
Gila River System and Source)

REPORTER'S TRANSCRIPT OF PROCEEDINGS

Evidentiary Hearing

Volume X

Phoenix, Arizona
February 15, 1994
10:40 a.m.

BEFORE: THE HONORABLE STANLEY Z. GOODFARB,
Judge of the Superior Court

Prepared by Teresa Louis,
Official Court Reporter

Again, to emphasize, all of the technical factors involved in the subflow criteria need to be specified by this Court's criteria if we are going to bring closure on this issue.

THE COURT: That's a hell of a task for a kid who had a tough time with plane geometry.

Let me ask you a couple of questions, Steve. What I want to start with is, if you'll get your sheet, your overhead of Exhibit 266. It's a green, red and yellow one. Let me see if I can utilize this to answer some simple questions that the Supreme Court raised.

First of all, Steve, would I be correct that the two black lines on the outer edge of the drawing are the ridge lines, correct?

THE WITNESS: These lines?

THE COURT: No.

THE WITNESS: This line?

THE COURT: Yes. That's the ridge.

THE WITNESS: Yes.

THE COURT: The other one is the ridge line to the east, ridge line to the west, right?

THE WITNESS: Yes.

THE COURT: On one side they got the Dragoons, on the other side I've got the Winchesters, and the line to the west is the Dragoons and ridge line

Again, to emphasize, all of the technical factors involved in the subflow criteria need to be specified by this Court's criteria if we are going to bring closure on this issue.

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THE WITNESS: Yes.

THE COURT: The other one is the ridge line to the east, ridge line to the west, right?

THE WITNESS: Yes.

THE COURT: On one side they got the Dragoons, on the other side I've got the Winchesters, and the line to the west is the Dragoons and ridge line of the Dragoons, the line to the east in this thing is the ridge line of the Whetstones, right?

THE WITNESS: To the west are the Whetstones.

THE COURT: Now, the gray area is hard rock. The yellow is basin fill aquifer, which really represents the debris from the geological erosion of the mountains as they grow up, isn't that correct?

THE WITNESS: That's correct.

THE COURT: It's transported by various streams, and part of it might have been transported by the Ice Age if the glaciers ever got down here, right?

THE WITNESS: Certainly. Over a very long period of time.

THE COURT: Now, in the middle of this there is a green area, and there are also some green areas along where there are probably the remains of ephemeral streams that were arroyos, and that constitutes the younger alluvium, right?

THE WITNESS: The younger alluvium formations. It is younger alluvium.

THE COURT: The younger alluvium formation is that erosive material which was deposited in various layers in the last 8500 or 85,000 years.

THE WITNESS: That's correct.

THE COURT: Now, the younger alluvium does not reach from ridge line to ridge line except where there are thin bands of younger alluvium along where the tributary waterways or arroyos go up almost to the ridge line.

THE WITNESS: That's correct. It occurs in very, very few places.

THE COURT: There's debris in arroyo and a channel that kind of fills it except for the places where you get to the hard rock, but there's always sand and some rock in any of these mountain canyons that are coming down.

THE WITNESS: Sure.

THE COURT: But the younger alluvium we've been talking about is that which fills the center of this valley, and that alluvium does not go from ridge line to ridge line, correct?

THE WITNESS: No, it does not.

THE COURT: According to your diagram here, the younger alluvium here, the solid, the large green area basically consists of the alluvium which is supportive of the stream and also constitutes a portion of the tributary aquifers that feed into the San Pedro, correct?

THE WITNESS: It could be viewed that way.

THE COURT: In fact of the matter, isn't the basin fill also a tributary, a part of the tributary aquifer because there's water there that slowly comes to the center, eventually gets to the center, and then starts drifting down the San Pedro to the Gila, and if it ever gets past Ashurst Dam it keeps on going clear down to the Sea of Cortez, to the Colorado and the Sea of Cortez. Takes a few eons in geologic time, but it does do that, doesn't it?

THE WITNESS: Yes. Conceptually that could occur.

THE COURT: Now, you've been talking about something that you call inliers. The Supreme Court basically talks about something called tributary aquifers. With regard to this exhibit, can we agree that that portion of the tributary aquifers which consists of the younger alluvium is that green which is outside of the red?

THE WITNESS: Within the context of the Supreme Court's order, the guidelines that they put down and the way that I understand that they were trying to separate tributary aquifer ground water from ground water associated with the stream, yes, I think you could say that ground water in these green areas would be associated with their definition of tributary ground water.

THE COURT: Unfortunately, the molecules of water are too stupid to understand the legal distinction between tributary aquifer and the subflow aquifer of the stream, right?

THE WITNESS: Not only are they too stupid, they don't care.

THE COURT: Probably the latter.

MR. SPARKS: They are probably teenagers, Your Honor.

THE COURT: If we were to draw a distinction between the ground water flow in what I call the tributary aquifer and the ground water flow of the aquifer below the San Pedro and shown in red, would it not largely be the direction of flow in that the tributary aquifer is headed toward the stream and the stream aquifer is headed in the direction of the stream?

THE WITNESS: I believe that could occur in many areas. This area of younger alluvium in the Pomerene-St. David area, as you well know, is occupied with extensive cultural development. Cultural development alters the natural course of ground water flow from a lot of different activities, pumpage and recharge incidental to use.

So flow directions can sometimes reverse. They can go one way one season and back again. But I think as a general way of viewing it, if water occurs in this area, if there's, for example, recharge and water levels in the aquifer in this area are higher than water levels at the stream, then naturally it's not going to travel down the basin through these inliers, but rather it's going to go flow more towards the stream. Because inliers, probably what there is there is older alluvium, and it probably has a lower hydraulic conductivity.

THE COURT: Let's take what you've told us and let's see if we can agree. If the areas shown in green in the natural condition, because water comes from high to low and those areas are obviously higher than the stream, in its natural condition before people started farming in there it flowed toward the stream, correct?

THE WITNESS: Yes, I believe it did.

THE COURT: In its subsequent condition, post-development, it may flow toward the stream, it may flow away from the stream, it may flow in circular conditions, it may flow in any one of many different directions.

But the stream only has an effect of having it flow toward the stream, but it flows in many directions and does not have a stream flow direction generally.

THE WITNESS: Well, yes, it's probably highly variable from location to location.

THE COURT: It's highly variable because of development.

THE WITNESS: Yes, because of development and because of the shape of these inliers and so forth.

THE COURT: Now, you've drawn these, and I understand why you've drawn them, and obviously I think we've drawn them because the Supreme Court shot down-- well, the Supreme Court having been told about tributary aquifers, which I never mentioned in my order and someone else raised for them, has shot down tributary aquifers, and therefore what they have said clearly, with no contest, is that you can't include tributary aquifers in the subflow, correct?

THE WITNESS: You can't?

THE COURT: Yes, you can't.

THE WITNESS: According to their--

THE COURT: Yes, according to their hydrologist.

THE WITNESS: That's correct.

THE COURT: Assuming I cannot shut down

tributary aquifers and assuming that the Page definition of subflow is to draw a band based on the closure where the inliers come, how can I be certain that where the inlier meets the stream aquifer, that the direction is sufficiently stream flow that I can draw the lines in that area?

Isn't this right where they meet some confusion of direction until it gets further into the younger alluvium and before I can be certain that its flow has straightened out sufficiently that I can in my mind be certain that flow with its elevation and its gradient is equivalent to the flow elevation and gradient of the stream?

THE WITNESS: You probably have seen with the surface water example, two streams come together. One is muddy and the other one isn't. You can see how the water is comingled. You can see how like the muddy one is the smaller stream, how it turns and goes down with the stream. It's pretty rapid. Things in an aquifer, movement is of course a different situation.

I suppose if you went out a little distance from the inliers, it would probably be a safe assumption that--

THE COURT: How far in from the inliers do you think I would normally have to come to be certain in my own mind that the stream flow has now turned sufficiently in its substance that it's going with the stream?

How far should I pull in those parameters to be certain in my own mind that I've now got subflow going in the same direction as the stream?

THE WITNESS: I don't think it needs to be too far, Your Honor, because as a normal consequence, normal situation with these inliers and younger alluvium associated with the tributary aquifers, the amount of water flowing in the aquifer towards the stream is probably going to be relatively small compared to the amount of water flowing down the stream.

THE COURT: Are you talking about 100 feet or 50 feet or 200 feet?

THE WITNESS: I would think it would be rare if it's more than 100 or 200 feet unless the inlier goes down a shallow slope.

THE COURT: In most instances the slope from the ridge line to the river is pretty good in this area, isn't it?

THE WITNESS: What I mean is, for example, let's say this inlier, if it goes underneath the younger alluvium material here at some shallow angle, it could be still an obstruction there, but I think that would be probably a rare situation.

So I would say than the order of 100 or 200 feet would probably be pretty certain that the general direction of the ground water was with the stream.

THE COURT: If I combined that with elevation, gradient and flow direction, in your opinion, hydrologically speaking, would that be a pretty safe assumption as to what would constitute subflow if we're talking about that saturated geological body which is supportive of and connected to the stream?

THE WITNESS: Yes, I think that would be appropriate.

THE COURT: Let's talk a little bit about post-entrenchment alluvium. You're familiar with the Hereford report, are you not?

THE WITNESS: Somewhat.

THE COURT: I'm going to read you something from an exhibit that was provided for us today, and see if you agree with this. This is page 46 of Exhibit-- do you know the number of this Oxford edition on Southwest Arroyos--

MR. PEARCE: 278.

THE COURT: Let me read you something that is kind of long but I think pretty well spells it out, and tell me whether or not you agree with it.

Page 46. "After about 1880 the possible causes of entrenchment multiplied. Drainage concentration could have been a factor. Climatic change might have played a role. There were several severe floods during the last two decades of the century, and these may have initiated entrenchment.

"Finally, there is a strong possibility that vegetation changes resulting from overgrazing within the watershed, especially south of Benson, cattle damage along the trails and the river, and deforestation of some catchment basins from mining timber may have promoted entrenchment."

Would you agree with that?

THE WITNESS: Yes, I would. I believe that there has been extensive testimony that all three of those factors--

THE COURT: Let me read you the next paragraph, because I think it really spells it out.

"Evidence of vegetation changes is extensive and conclusive. It is recorded on numerous photographs reproduced in Hastings and Turner's (1965.) Rodgers (1965) reviewed the evidence in this southern San Pedro Valley. He argued that there appears in his view to be

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Deputy

Nº W-1, W-2, W-3, W-4

In re the General Adjudication of All Rights to Use Water in the Gila River System and Source

ORDER

THE NATURE OF THESE PROCEEDINGS

On July 27, 1993 the Arizona Supreme Court decided In re the General Adjudication of All Rights to Use Water in the Gila River System and Source, 175 Ariz. 382, 857 P.2d 1236 ("In re Gila") and remanded it back to this Court to make certain evidentiary decisions. That opinion was the second of six issues of law the Court accepted for interlocutory review on December 11, 1991. Those issues were accepted because this action, which adjudicates water rights under the McCarran Act, 43 USCS § 666, will be before the Courts for many years and is exceedingly complex.

Two issues were remanded. First, a test for use by the Arizona Department of Water Resources (ADWR) to determine what is known as "subflow" under Maricopa County Municipal Water Conservation District No. One v. Southwest Cotton, 39 Ariz. 65, 4 P.2d 369 (1931) ("Southwest Cotton"). "Subflow" contains appropriable water under A.R.S. § 45-141 and, therefore, is subject to the jurisdiction of this Court under state law. In this Court's opinion, "In re Gila" requires that the "subflow" zone be defined by physical factors utilizing stable geologic formations, available hydrological information, and/or organic characteristics of the area. Second, a test for use as to wells outside the "subflow" zone which create such a "cone of depression," that they cause water to be lost to or removed from the "subflow" zone, the stream bed, or the stream itself.

The parties divide into two groups. The United States, Salt River Project, the Indian Tribes and the Nature Conservancy argue for a "subflow" zone as wide as possible and a "cone of depression" test which provides the greatest protection to stream flow. These parties have an interest in protecting their surface rights in stream flow because they already have appropriation rights or federal reserve rights under Winters v. U.S., 207 U.S. 564, 28 S.Ct. 207, 52 L.Ed 340 (1908). Those who refer to themselves as the "groundwater users" include the mines, several cities who depend more heavily on groundwater sources, plus certain agricultural interests. They argue for a much narrower "subflow" zone, because it provides much more protection for their use of sub-surface water sources they depend on.

On August 27, 1993 this Court took up the issues presented and the resolution process. At least two of the parties, Cyprus Mining and the City of Phoenix, previously presented requests for direction. A briefing schedule was set and request for comment on the issue with argument set for October 7, 1993. By then the Court had received a number of briefs which called for an evidentiary hearing. The Court agreed and provided certain specific orders to ADWR and others on how the evidentiary hearing would be held, how reports were to be prepared, how experts were to be presented and proposed dates and schedules.

On November 5, 1993 there was further discussion as to the contents of the experts' reports filed by December 15, 1993. The next meeting, December 10, 1993, changed the date of the evidentiary hearing from January 10, 1994 to January 31, 1994, spelled out what was expected from the parties as to testimony, and set rules on cross-examination by multiple parties and limits on evidentiary relevance.

On December 22, 1993 the Court held its first Pretrial Management Conference and set down four separate evidentiary rulings which the Court believed all parties were in agreement with, and noted what seemed to be the quality of the ten separate reports filed. The Court then requested an acetate overlay presentation of how each party's position would show the parameters of the "subflow" zone in two typical study reaches of the San Pedro Basin. They were Reach 1 between Reddington and Mammoth (exhibit 18), and Reach 2 Palominas (exhibit 11). The acetate overlays were mounted over base maps prepared by ADWR and marked as exhibits 12 to 17 for the Palominas Reach (exhibit 11), and exhibits 19 to 25 for the Reddington Mammoth Reach (exhibit 18).

On January 14, 1994 the final details were worked out, the requested exhibits presented, mounted and viewed by all counsel, a schedule of the order of witnesses' presentations arrived at and how cross-examination would be allowed. By then an exchange of exhibits was to have occurred. Between the 14th and the 31st, disclosure statements were filed by the City of Phoenix, Maricopa County, City of Tucson, City of Benson, Apache Nitrogen, Buckeye Irrigation, City of Tempe, Apache Tribes and the Verde Valley who did so to preserve their right of cross-examination but who did not intend to offer any expert testimony and had not submitted reports.

On January 27, 1994 the groundwater users filed a disclosure statement indicating for the first time a claim that the parameters of the "subflow" zone would be defined by the lateral limits of what they called the "post-1880 entrenchment" rather than what they reported previously in Dr. Montgomery's Report of December 14, 1994. During the ten days of the hearing the "post-1880 entrenchment" theory became the focal point of their position.

On Monday, January 31, 1994 this Court commenced ten days of evidentiary testimony taken from ten different geologists and hydrologists. March 3 and 4, 1994 were spent on a field trip to the San Pedro itself. (Two hundred eighteen exhibits were then received in evidence.) Before testimony started, two sides presented oral motions to exclude the other's testimony. The groundwater users requested exclusion of all testimony as to younger alluvium arguing that "In re Gila" precluded it. Salt River Project, the United States and the Tribes argued to exclude any testimony as to the "post-1880 entrenchment" theory because it was revealed only two court days before the hearing. Both motions were denied for the reasons stated on the record.

Testimony started on January 31, 1994 with Jon R. Ford for Salt River Project who was followed by Dr. Thomas Maddock, III, of the University of Arizona for the Nature Conservancy, Oliver S. Page for the United States, and T. Allen Gookin for the Gila River Indian Community. Following them were Dr. Errol L. Montgomery and Dr. Stanley Schumm, a geomorphologist from Colorado State University, who presented the groundwater users' position. William Wellendorf, David Stephenson and Michael Lacey followed for certain cities on February 10, 1994. Testimony then ended on February 15, 1994 with two days of Steve Erb, Chief of the Adjudication Section of ADWR.

In the testimony it soon became apparent that almost none of the experts had done any recent physical investigation on the San Pedro. What they presented largely were literature searches and investigation of their own or others' prior reports. No drilling or soils investigation had occurred. The Court, based on its own prior experience as counsel for the Arizona Department of Transportation (ADOT), recalled that the materials division of ADOT keeps a detailed index of all soils investigation made for highways constructed, bridges built and materials pits utilized for its construction in every part of this state. Since there were highways all over the San Pedro Valley, the Court had ADWR contact ADOT and discovered that it had drill logs available for the two interstate highway bridges at Benson in the San Pedro River, the bridge over the river at Charleston and the bridge at Lewis Springs. These were secured and copies made available to all parties for their use and interpretation. (These were marked as exhibits 236, 237, 238 and 239 and testified to extensively by Dr. Montgomery, Steve Erb and others). While a number of witnesses testified about opinions based upon well-driller logs of record at ADWR, after receiving the ADOT logs the United States, Salt River Project and groundwater users moved extensive drilling equipment into the area and drilled several sites in both the upper and lower reaches of the river. The information derived from these drilling programs plus interpretation of the ADOT drilling logs is contained in the rebuttal affidavits filed by Jon R. Ford, Oliver S. Page and Errol L. Montgomery. These were filed in lieu of further rebuttal testimony.

On March 3 and 4, 1994 the Court and a large number of counsel embarked on a two-day, 595-mile field trip covering the entire San Pedro Valley and visited more than 13 sites. There each expert was permitted to explain the geology and hydrology of the site. This was recorded by audio tape, transcribed and filed of record. It is 258 pages because at nearly every site discussion was lengthy, often at odds, and sometimes heated. The statements were first made by witnesses previously sworn at the hearings; but, by consent, statements were also taken from others including several long-time residents who were witnesses to facts of historical significance with regard to the river. These were Jack Smallhouse, a rancher in the area of Reddington whose family resided and ranched the area since 1880; Barbara Clark, a resident at Cascabel who had resided in the present location adjacent to the river for about twenty years; and Ben Lomeli, a hydrologist for BLM who is a ranger for the San Pedro River Riparian Conservation Area. A detailed discussion of the trip is contained in this Court's minute entry of March 11, 1994.

At the conclusion of the hearing on February 15, 1994, the Court established a schedule for briefing. Principal lead counsel were to file their briefs by March 18, 1994. Others were to reply by March 25, 1994. After this was done, the groundwater users filed a Motion to File a Reply Brief and a request for oral argument. Salt River Project and the United States moved to strike and deny. The Court allowed those late briefs to stand but denied oral argument. More than enough had been said and written.

Later, as will be explained on pages 39 to 42 of this decision, it became necessary that a supplementary evidentiary hearing be held. It related to a comparison of aerial photography of the San Pedro River taken in 1935 and 1990. When this Court became aware of this material, it asked ADWR to carry out a study comparing the physical features of the river shown on this aerial photography which was taken fifty-five years apart. The request was to look for any changes in the location or size of the principal channel of the river or the riparian vegetation areas adjacent to the river. This hearing occurred on June 14 and June 15, 1994. Four witnesses were heard from and 83 additional exhibits were admitted.

Prior to and since that hearing this Court has reviewed all of the testimony given, all of the exhibits, participated fully in the field trip and read all of the briefs. It also re-examined the testimony and exhibits of the 1987 evidentiary hearing on the relationship of groundwater to surface water. It finds a sufficient foundation of facts needed to rule on the issues presented. Because one of the criticisms of this Court's prior instruction to ADWR on the "50%/90-day" rule was a lack of evidentiary record to support it, this order will be necessarily lengthy.

THE REASONING PROCESS WHICH LED US HERE

Having discussed the nature of the proceedings from July 27, 1993 to date, it should help to understand the decision which follows to review the thought processes which brought us here.

This McCarran Act adjudication began as a judicial process in 1979. It combines an adjudication of rights under Arizona law of prior appropriation for surface water sources, "Southwest Cotton," with the non-prescriptive right under state law to reasonable use of groundwater, Bristor v. Cheatham, 75 Ariz. 227, 255 P.2d 173 (1953), with federal law on the rights of federal entities and Indian tribes to use both surface and groundwater for the purpose of the federal entity and/or reservation creation. Cappaert v. U.S., 420 U.S. 128, 965 Ct. 2062, 48 L.Ed.2d 523 (1978). It must deal not only with rights derived from actual use under state law, but with priorities of rights reserved to federal entities and reservations under federal law because the United States is not only the owner but the Trustee of those lands, Winters v. U.S., supra.

Unfortunately, from 1979 to 1983 this case was involved in a jurisdictional dispute which was not resolved until 1983 in Arizona v. San Carlos Apache Tribe of Arizona, 463 U.S. 545, 103 S.Ct. 3201, 72 L.Ed.2d 837 (1983). After that, it took a great deal of time to bring the Hydrographic Survey Report (HSR) activities of ADWR to the point where the voluminous reports needed could be readied for judicial analysis and decision. Considering the size of the Gila watershed, its numerous sub-watersheds, the number of claimants (approximately 24,000), and the diversity of interests, that should not be surprising. While the investigation for the reports was being carried out and reports prepared, the Court, in order to use its time efficiently, attempted to hear and decide major issues which were not factually oriented. As a result, the Court issued a series of pretrial management orders and decisions including the ruling of September 9, 1988 which included the "50%/90-day" rule. As stated in "In re Gila," P. 384 of 175 Ariz:

> "For five days in October, 1987, the trial court held hearings on the relationship between surface water and groundwater. Hydrologists and hydrological engineers testified and submitted reports on the relation between ground and surface water in general, and in the San Pedro and Santa Cruz watersheds in particular. The hearings were for the general education of all parties and the court, but the material adduced at the hearing was to be considered evidence on which the court could rely when appropriate."

A review of the exhibits and testimony of that hearing reflects the issue of "subflow" or how it could be physically located was not the focus of those hearings. Rather, it was a hearing as to the general relationship of surface flow to groundwater of all types. Then, and even at this latest hearing, the consensus of all testimony was that there is a hydraulic connection between nearly all groundwater and the surface flow in its area except where: 1) a confined aquifer is sealed off from surrounding basin fill or floodplain alluvium by substantial impervious layers such as clay which precludes the connection; or, 2) a groundwater aquifer is beneath an ephemeral stream and the "vadose" dry zone between the stream and the top of the aquifer substantially precludes connection.

Following the 1987 hearings, several cities filed a motion to exclude certain wells from the adjudication arguing they pumped percolating groundwater rather than surface flow or "subflow" under "Southwest Cotton." It was at this point that the "subflow" issue first significantly arose in this case and the Court's instruction to ADWR on the "50%/90-day" rule was issued on September 9, 1988. While "In re Gila" is correct in that there was no substantial evidentiary basis for that instruction, the reason for it was that the 1987 hearings did not focus on "subflow."

In dealing with the issue of "subflow" as raised in "Southwest Cotton," the hearings held in January, February, March and June 1994 specifically focused on it. All its testimony related directly to that issue and the issue of "cones of depression."

Another fact needs to be recognized. On page 391 of 175 Arizona Reports, the following statement appears:

> "The trial court instructed DWR to apply the 50%/90 day test to all wells located in or near the younger alluvium. <u>The record shows, however, that in a given area the younger alluvium may stretch from ridge line to ridge line so that all wells in the valley would be in or near the younger alluvium</u>." (emphasis supplied)

The position of the second sentence that "younger alluvium may stretch from ridge line to ridge line" is factually unsupported. Every witness who testified in this hearing agreed that "younger alluvium" "Holocene alluvium" or "floodplain alluvium" (different names for the same thing) is found only in the center of this broad valley. It does not come even close to the ridge line in the upper or lower basins of this valley. Those ridge lines constitute the top of the Huachuca and Whetstone Mountains to the west and the Dragoon and Mule Mountains to the east in the upper basin from the border to Pomerene. The valley in this area is a basin fifteen to twenty miles wide.

If one proceeds geologically from the ridge line of the mountains down toward the center of the valley one encounters first substantial rock face, then some distance from the top and generally at their base the edge of the basin fill deposits. These divide geologically into an upper and lower basin fill.

Moving further toward the center of the valley one encounters the edge of what this Court will call the floodplain alluvium near the center of the valley. It is made up of those deposits laid down since the end of the "Ice Age." Its width is up to 7,000 feet in the upper basin and much narrower in the lower basin which runs from Pomerene north to Winkelman. There the ridge line is the top of Rincon and Tortilla Mountains to the west and the Winchester and Galloros to the east. The same geologic sequence of ridge line, rock face, basin fill, and finally floodplain alluvium is also found in the lower basin.

Most aquifer recharge occurs at the line of mountain front recharge. This is where the basin fill meets the rock face. It is generally thousands of feet below the ridge line and miles from the floodplain alluvium. The graphic portrayal which follows shows this relationship.

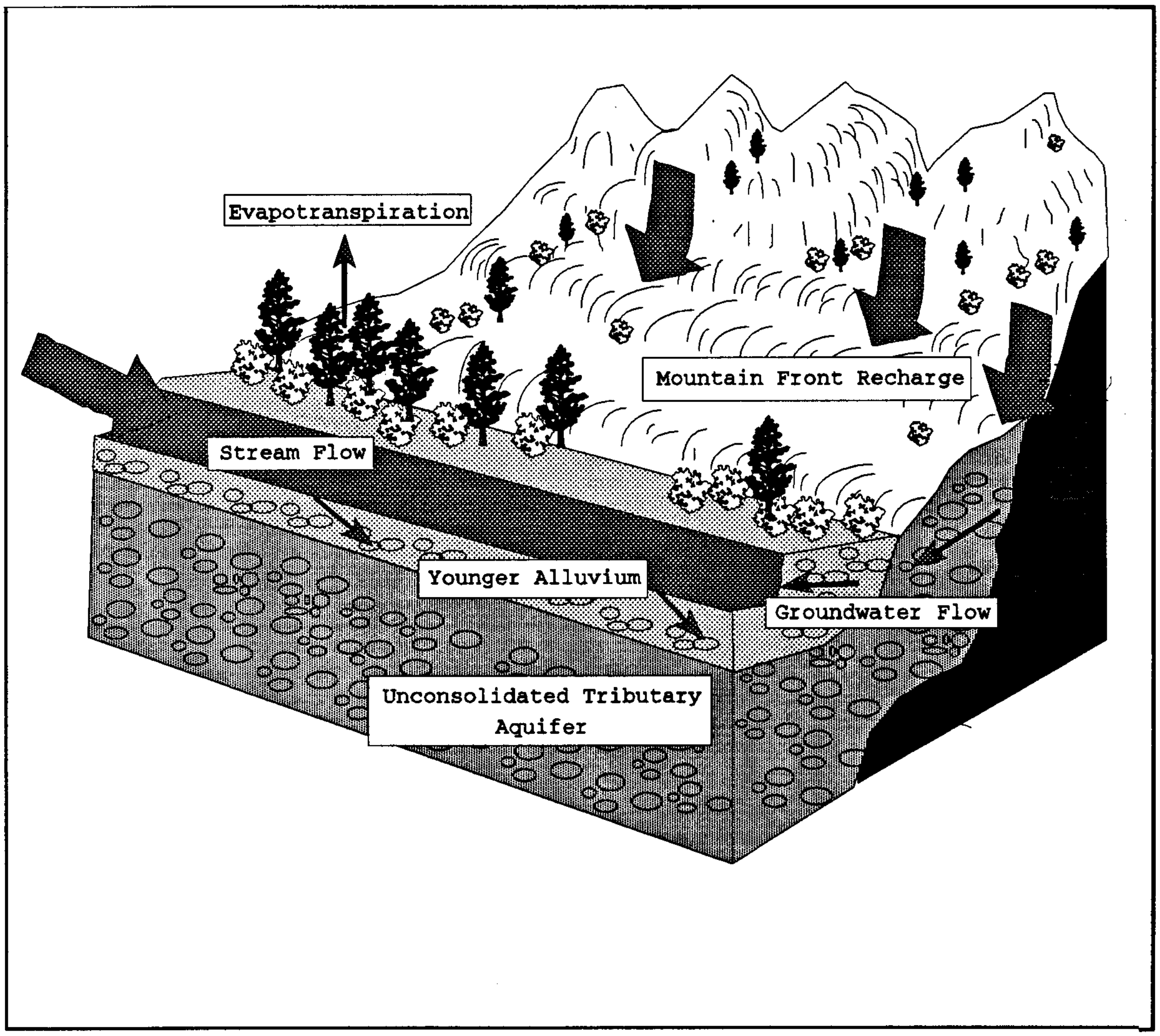
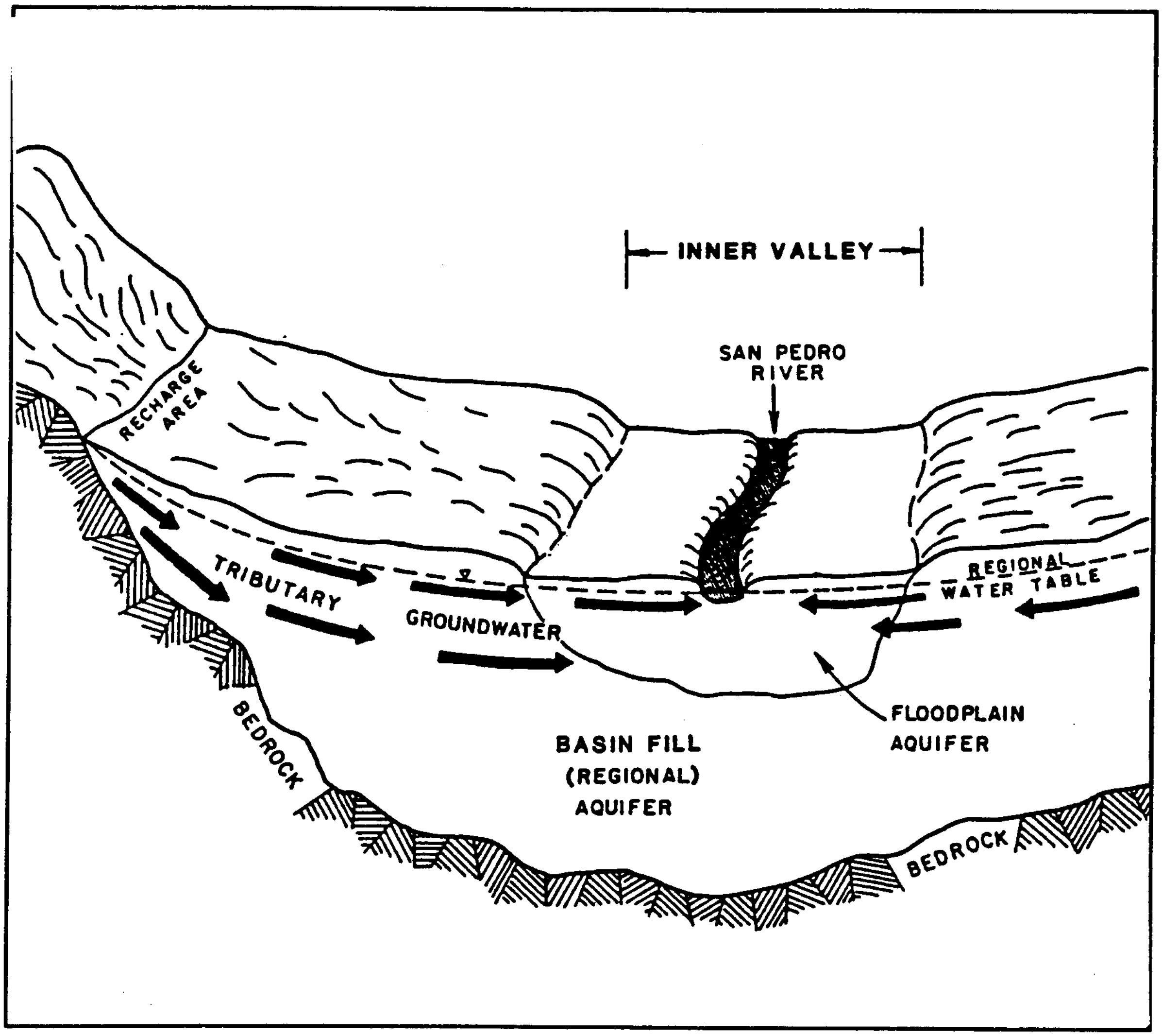


Figure 2-3. Generalized cross-section of aquifers systems.

Copy of Page 13 of Exhibit 10.



(Modified from ADWR, 1991)

Copy of figure 4 of Exhibit 2.

THE SAN PEDRO RIVER

While the issues to be decided pertain to watersheds all over the Gila River watershed, the facts as to the San Pedro River need to be discussed.

The San Pedro River Valley is in the basin and range portion of southeast Arizona. It is oriented from south to north and flows from Cananea, Sonora, Mexico, to Winkelman. The valley's elevation ranges from 9,500 feet at its mountain tops to 1,920 feet at Winkelman. At the international border it is at 4,275 feet and drops to 3,590 feet at the narrows near Benson. In the United States the San Pedro River runs about 52 miles from the border to Benson and another 80 miles to Winkelman for a total of 132 miles. Its overall rate of drop is about 18 feet per mile but in the upper basin it is 13 feet per mile and 20 feet per mile in the lower basin.

According to the HSR prepared by ADWR, Table 4-12, the river naturally and normally produces approximately 160,000 acre feet of surface water per year. Approximately 64,000 acre feet is used by various cultural uses such as irrigation, mining, domestic, municipal, etc. Another 5,620 acre feet is lost to evaporation and 52,000 acre feet is used by the phreatophytes such as willow, cottonwood and mesquite which make up its riparian forests. This leaves about 58,000 acre feet of outflow both by groundwater and surface water at Winkelman into the Gila River system after recharge and return from some of the cultural and natural uses. Dr. Montgomery, in his October 2, 1987 Report for the earlier hearing (exhibit 11 of that hearing), reported on page 2 that the lower basin of the San Pedro alone had water storage capacity of 30 million acre feet in its aquifers. ADWR estimated in the HSR that the storage capacity of the San Pedro Aquifer both upper and lower was 84 million acre feet. Attached as Appendix A is that portion of this river's HSR which estimates its groundwater storage capacity by sub-watersheds and in total. Also attached is the water balance portion of the HSR and the aquifer storage estimate (Appendix B and C-1, C-2, C-3). In comparing these capacities to what appears to be a relatively low surface flow component, it is clear this river value as a water asset is largely in its storage capacity rather than its surface flow.

An important and unexpected bit of evidence in our case was exhibit 190, Geological Society of American monograph entitled "Entrenchment and Widening of the Upper San Pedro River, Arizona" written by Richard Hereford, a direct descendant of the founder of the town of Hereford. He provides an interesting history prior to development and post-development of the upper basin from the border to St. David. Basically what he reports is that prior to 1880 the San Pedro was a slow, swamp-like river running through various cienegas abundantly filled with large buffalo fish and beaver dams. The swamp-like conditions caused malaria in the early St. David settlements until breaching the beaver dams allowed the swamps to drain. The areas beside the river were large grassy plains with little riparian forestation. A picture of the bridge at Hereford in 1908 is shown on page 15 of exhibit 190. It shows no trees in the area and a large grassy plain next to a stream entrenched a few feet below the surface of the adjoining grasslands. On our field trip on March 3, 1994 we found a virtual forest of riparian growth nearly a mile wide.

Upper San Pedro River, Arizona

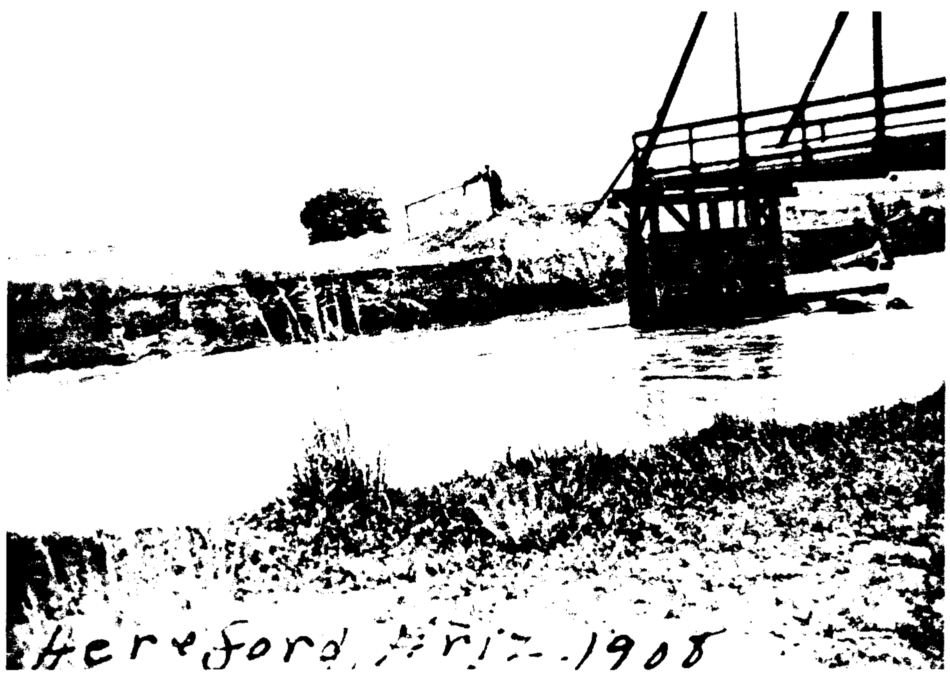


Figure 14. Photograph of the Hereford bridge in 1908 showing entrenched channel. View is upstream. Photograph from Bisbee Mining and Historical Museum.

Exhibit 190 page 15.

In Hereford's Report, page 19, there are pictures taken at the Palominas bridge in 1939 and 1991 which also show the very recent heavy phreatophyte forestation. The Court's recent visitation to the area indicated even heavier growth and a channel significantly narrower from that shown even in the 1991 photo. On March 3, 1994 the Court found a lengthy three-span highway bridge, but a channel so narrow that one could jump across it, as several did, lodged against the eastern span of the bridge in the two pictures (one taken in 1939 and the other in 1991) that follow.

(A)

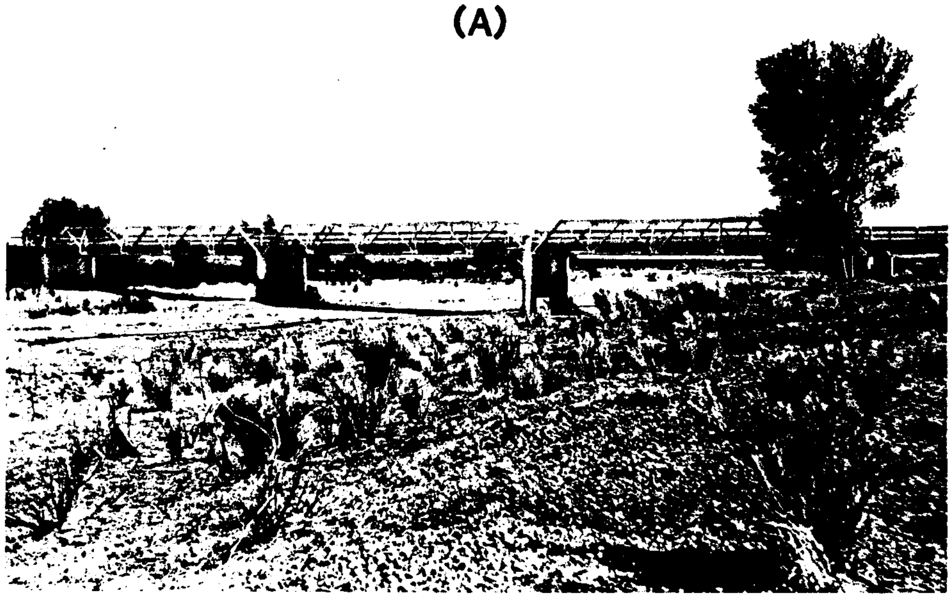


Exhibit 190 page 19.

Figure 17. Palominas bridge; view is upstream. (A) Photograph taken in 1939 (from Special Collections, University of Arizona, Tucson); (B) 1991. Dense riparian vegetation has developed in the channel.

Exhibit 190 page 19.

The reports and testimony all indicate a vastly different river environment up to 1880. Thereafter, significant overgrazing of the grass cover, removal of most of the upland trees for mine and charcoal use, climatic changes, phreatophyte growth and even, it is claimed, an earthquake in Mexico drastically changed this valley. The vast herds of cattle of the late 1800s and early 1900s stripped most of the grassland cover from the adjacent parts of the lower basin allowing significant erosion and phreatophyte infestation. The climate changes and overgrazing helped change the river from a slow-moving, marsh, swamp, cienega-like environment to one where heavy flash floods through narrowed channels could cause deep entrenchment and deposition. However, as Hereford reports, this entrenchment occurred mostly at times of significant flood, and nearly all of the new deposition occurred post-1937.

> "The post entrenchment deposits of the San Pedro River are confined entirely within the entrenched channel; most were formed after 1937." (p. 19 of exhibit 190)

A view of the diagrams and photographs of the reports supports the positions of Ford, Page, Gookin and Erb that the "post-1880 entrenchment" of this river is simply the latest subset of a depositional process which began after the "Ice Age" and continued to date. It provides the most recent layer added to what is generally called the "Holocene" alluvium. Of all the photographs of importance in the Hereford Report, figure 11, page 12 clearly show that a deposition of flood-bank alluvium which, according to Hereford, is as recent as 1955. It is not as highly permeable or clay free as witnesses for the groundwater users urged in attempting to contrast the same with the general Holocene alluvium unit in which this latest deposition layer is inset. In a bank of no more than 6 or 7 feet there are six layers of clay showing recurring periods of deposition. Moreover, other photographs which are designated as figures 3, 4, 11 and 12 (exhibit 190) show a high degree of comparability between units of pre- and post-entrenchment depositions. Copies of these photographs follow.

Figure 11. Photograph of cutbank exposure of older floodplain alluvium (unit f_1) on west side of river 1 km south of Lewis Springs. Downstream to right. Thin dark layers are silty clay. Scale divisions = 10 cm.

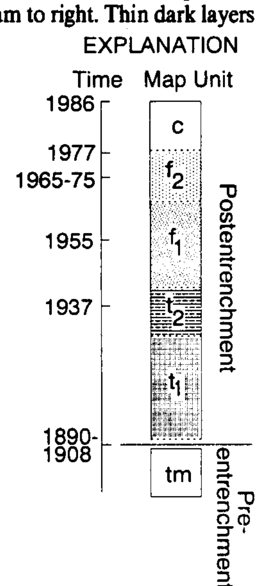


Exhibit 190 pages 8 and 12.

Figure 12. Photograph showing cutbank exposure of younger floodplain (unit f_2) alluvium with truck tire 0.6 km south-southwest of Contention. Scale divisions = 20 cm.

Exhibit 190 page 12.

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In Re The Adjudication of: Continued

Figure 4. Photograph showing the geomorphic and cut-and-fill stratigraphic relation of the post- and pre-entrenchment alluvium on the east side of the river 3.2 km north of the Charleston gaging station. Postentrenchment alluvium (unit t_l) forms the lower surface on the left side of the photograph. Upper surface is the pre-entrenchment McCool Ranch alluvium (unit t_m) overlain by Teviston alluvium. Note truncation of beds in the older unit. Map units discussed in text. Scale divisions = 20 cm.

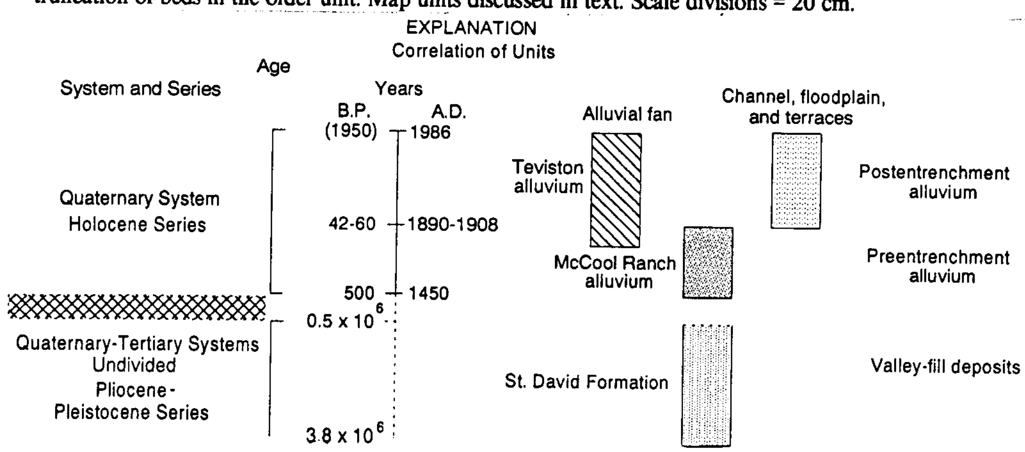

Figure 2. Geologic cross section showing correlation of surficial deposits and geomorphology of the inner valley of the San Pedro River in the vicinity of Lewis Springs. The geologic relations, geomorphology, and deposits are typical of the study area.

Exhibit 190 pages 6 and 8.

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Upper San Pedro River, Arizona

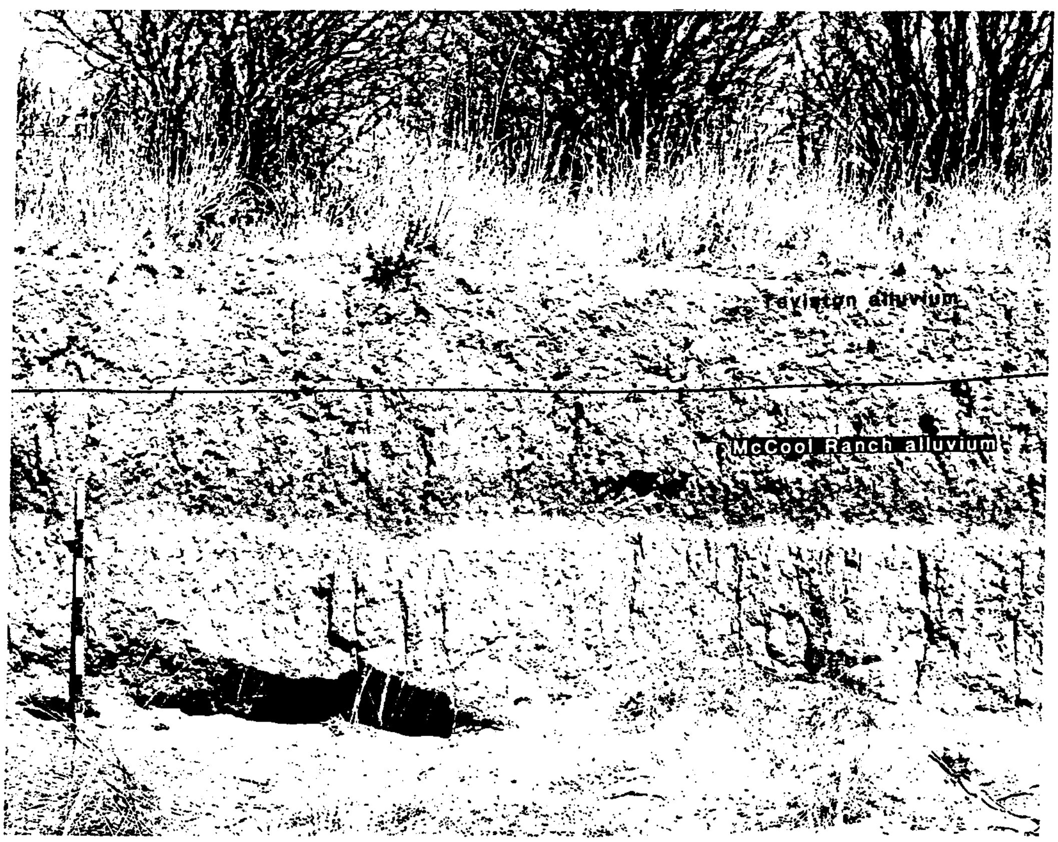

Figure 3. Photograph of a typical exposure of the pre-entrenchment alluvium 4.9 km north of Hereford. Upper Holocene Teviston alluvium overlying the McCool Ranch alluvium of Haynes (1987). Note the dark bed of cienega-type deposits near top of scale. Subhorizontal line shows contact between the alluviums. Scale divisions = 20 cm.

Exhibit 190 page 7.

HYDROLOGIC PRINCIPLES

Hydrology is the study of the properties of water. It is a multi-disciplined science encompassing the study of physics, chemistry, geology, geography and climatology. Like many sciences, it depends upon the acceptance of certain principles agreed upon by most hydrologists. To understand the evidence received one should understand the hydrologic principles to which all the witnesses agreed.

ADWR's Report of December 15, 1993 (pages 4 to 19, exhibit 10) states them as follows:

Hydrologic Overview

> "The alluvial basins of the arid West are integrated hydrologic systems composed of surface water and groundwater components. Water in these systems flows from areas of high elevation to areas of lower elevation along a path of greatest slope under the influence of gravity. Major perennial or intermittent streams occur in the central portion of the alluvial basin, occupying the lowest areas of the basin floor, flowing along the slope of the basin. The perennial or intermittent stream is typically surrounded by younger alluvium. Surface flow in the stream is derived from runoff from precipitation and groundwater discharge. Groundwater flows in unconsolidated and consolidated aquifers from the mountain fronts at the margins of the basin toward the center, occupied by the younger alluvium and the stream. Upon nearing the center of the basin in the vicinity of the younger alluvium, groundwater flows under the influence of the basin slope, in the same direction as the stream.

The physical character of groundwater and surface water in the vicinity of the younger alluvium is often identical. Surface water and groundwater in the area occupy the same geologic space and flow in the same direction along the slope of the basin. There is free interaction between groundwater and surface water; groundwater in the younger alluvium contributes to the surface flow and the surface flow recharges the younger alluvium. Distinguishing between groundwater and surface water in the vicinity of the younger alluvium in hydrologic terms to derive a legal standard is problematic and a byproduct of Arizona's bifurcated legal system." (pages 4-5)

Stream Types

"Surface water streams fall into one of three types: perennial, intermittent, or ephemeral. The type of stream is indicative of the extent of groundwater/surface water interactions taking place." (page 6)

"Perennial streams discharge water continuously through the year. Their source of supply is normally comprised of both direct runoff from precipitation events or snow melt, and baseflow derived from the discharge of groundwater into the stream." (page 6)

"Intermittent streams discharge water for long periods of time, but seasonally. For example, an intermittent stream may flow all winter, every winter, but never flow continuously during the summer. During seasons when baseflow is maintained, groundwater is contributing to the stream. During seasons of discontinuous streamflow, natural and cultural losses may be greater than the contribution from groundwater, resulting in a losing stream. Or, the amount of groundwater discharge itself may have decreased due to natural or cultural uses." (page 6)

"Ephemeral streams discharge water only in response to precipitation events or snowmelt, and do not have a baseflow component at any time of the year; they flow out sporadically. The groundwater system and surface water system do not establish a hydraulic connection in these systems." (page 9)

Aquifer Types

"Aquifers are saturated geologic units that can transmit significant quantities of water under ordinary hydraulic gradients.... There are three types of aquifers identified in this study: younger alluvium, tributary aquifers, and nontributary aquifers. While these aquifers are distinct hydrogeologic units, they are interrelated parts of the dynamic groundwater system." (page 10)

Younger Alluvium

"In the Gila River system, younger alluvium aquifers are unconsolidated sand and gravel deposited within the channel course of perennial or intermittent streams by the stream itself.... Groundwater in the younger alluvium is derived in large part directly from the stream system. The hydraulic gradients and groundwater flow directions are similar to the associated surface water stream. The groundwater table elevation in the younger alluvium is at or near the surface elevation of the stream.

The younger alluvium is a relatively thin aquifer. In the San Pedro river [sic] watershed, the younger alluvium ranges from approximately 10 to 200 feet thick. Also, the younger alluvium occupies only very narrow portions of the alluvial basins within the Gila River system."

....

"The younger alluvium occurs within, and defines, the channel of perennial and intermittent streams in the Gila River system. It underlies and laterally grounds the associated stream and is a hydrogeologic feature of the stream. The material that comprises the younger alluvium was deposited by the stream in the recent geologic past." (page 10)

"Conceptually, the stream builds its channel through scouring and fills it by deposition, thus creating the younger alluvium. Throughout geologic time, river systems have complex scouring and depositional histories as a result of the external and internal forces at work within the system.... These processes proceed at a geologic pace and are continuing today, defining the younger alluvium." (page 11)

Tributary Aquifers

"Tributary aquifers occur between impermeable mountain fronts and younger alluvium. They receive water from mountain front recharge and infiltration from runoff. The aquifers are in direct hydraulic connection with younger alluvium and transmit water to younger alluvium. The tributary aquifers normally have hydraulic gradients distinct from the hydraulic gradient of surface water streams and have flow directions toward surface water streams unless altered by well pumping." (page 11)

Nontributary Aquifers

"Nontributary aquifers are located in isolated groundwater basins surrounded almost entirely by impermeable hardrock with relatively narrow connections to other groundwater basins and aquifers. Nontributary aquifers have no hydraulic connection with either the younger alluvium or tributary aquifers. Any stream overlying a nontributary aquifer is ephemeral." (page 12)

Aquifer Flow Characteristics

"Aquifers are more than just reservoirs of groundwater. They are dynamic systems that receive inflows of groundwater, transmit groundwater and, in some cases, discharge groundwater to surface streams.... The inflow of water recharge occurs from the infiltration along mountain fronts and stream channels, and from infiltration of excess water from cultural uses. Aquifers that border high mountains normally receive significant mountain front recharge and recharge from streamflow infiltration. Aquifers that underlie large areas of agricultural irrigation experience significant recharge incidental to the irrigation practices.

Groundwater in transit will eventually discharge to a stream if not first withdrawn by natural (plant life) or cultural uses (pumpage from wells)." (page 12)

"There are four types of groundwater/ surface water interactions in the Gila River system: Alluvial valley streams, alluvial valley streams with confined zones, bedrock canyon streams, and mountain front streams." (page 14)

<u>Alluvial Valley Streams</u>

"Alluvial valley streams are perennial or intermittent streams that flow in alluvial basins and are underlain and bounded by younger alluvium. The alluvial basin is a structural trough filled with unconsolidated sediments derived from the adjacent mountains. These unconsolidated sediments are generally referred to as basin fill deposits (Anderson, and Johnson, 1985). The perennial or intermittent stream commonly occupies a narrow inner valley, composed of younger alluvium, which includes the dynamic channel of the stream.

A generalized cross-section of an alluvial valley stream segment is shown in Figure 2-4a. As depicted in this figure, the younger alluvium and perennial stream occupy the inner valley.

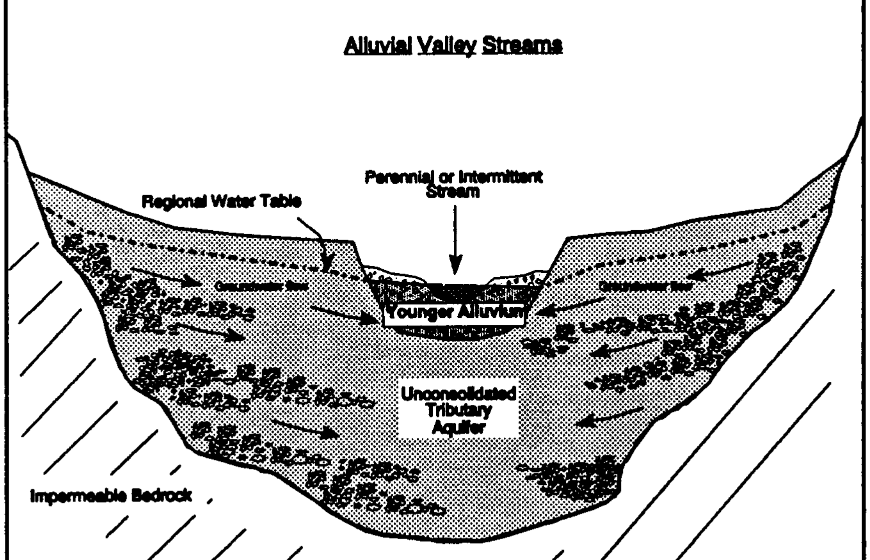

Figure 2-4a. Generalized cross-section of allvuial valley stream segments.

Page 15 of Exhibit 10.

The overall groundwater system within alluvial valley stream segments has two broad components: groundwater flowing toward the stream system, and groundwater flowing with the stream system. The groundwater flowing toward the stream occurs in the tributary aquifer. Groundwater in the younger alluvium generally flows in the same direction as the stream but, to a lesser degree, also from the adjacent tributary aquifer." (pages 14-16)

<u>Alluvial Valley Streams With Confined Zones</u>

"Alluvial valley stream systems sometimes contain tributary aquifers with underlying confined zones. The confining layers in the tributary aquifer are composed of impermeable silt and clay (Anderson, and Johnson, 1985). The confining layers prevent vertical movement of water from the underlying tributary aquifer to the overlying younger alluvium in particular locations (Figure 2-4b), thus interrupting direct hydraulic connection between the two aquifers. It must be noted, however, that these situations occur only occasionally; whether a particular well withdraws water only from a confined zone should be determined on a well by well basis." (page 16)

Alluvial Valley Streams with Confined Zone

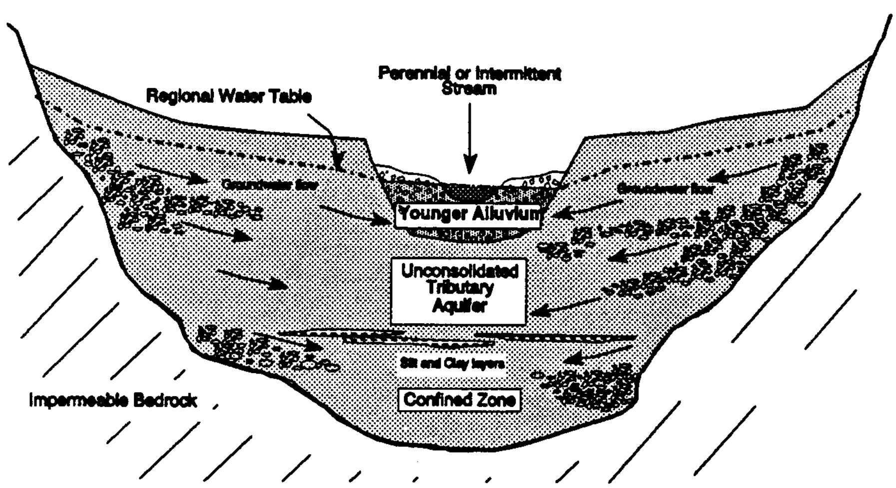

Figure 2-4b. Generalized cross-section of alluvial valley streams with confined zones

Page 17 of Exhibit 10.

Bedrock Canyon Streams

"Bedrock canyon streams are perennial or intermittent streams located in canyons bounded by consolidated tributary aquifers or impermeable bedrock." (page 16)

Mountain Front Streams

> "Mountain front streams are stream segments in transition from bedrock canyons to alluvial basins...." "The streams are perennial or intermittent and are underlain and bounded by younger alluvium. Many streams make a transition from bedrock canyon streams, with narrow younger alluvium bounded by hard rock, to alluvial valley streams with younger alluvium bounded by tributary aquifers." (page 19)

Three other definitions need to be set out.

Vadose Zone - An unsaturated (dry) zone above the water table (open to atmosphere) where water pressure is less than the atmospheric pressure.

Permeability - The rate of hydraulic conductivity of the material the water is passing through (refers to aquifer).

Transmissivity - The rate of hydraulic conductivity multiplied by the height of the geologic unit it is contained in.

WHAT DOES "IN RE GILA" REQUIRE

Unfortunately, the term "subflow," which "In re Gila" deals with, has no scientific meaning in the vocabulary of hydrologists or geologists. It is a term only lawyers and judges use. Every witness said that. All we can do is apply their scientific principles to find a reasonable factual basis in which to enwrap the legal concept of "subflow." To do that we must review the language of "In re Gila."

On page 388 of 175 Ariz., the Court quoted with approval the following from "Southwest Cotton":

> "there cannot be any abstraction of the water of the underflow without abstracting a corresponding amount from the surface stream, for the reason that the water from the surface stream must necessarily fill the loose, porous material of its bed to the point of complete saturation before there can be any surface flow."
>
> ...
>
> "The test is always the same: Does drawing off the subsurface water tend to diminish appreciably and directly the flow of the surface stream? If it does, it is subflow."
>
> On page 391 it says of "Southwest Cotton":
>
> "It seems clear that the court considered subflow and tributary groundwater to be two different classes of underground water. The former is subject to appropriation under the predecessor of A.R.S. § 45-141(A); the latter is not."

On page 390 the present court quotes Kinney's 1912 work on "The Law of Irrigation and Water Rights" that "subflow" is "strictly confined to the river bottom" and "the water must be within the bed of the surface stream itself." Yet on page 391 of 175 Ariz., the case states an opinion more in conformity with present science and at odds with Kinney's narrow-bed theory:

> "We believe the <u>Southwest Cotton</u> court drew a line between subflow as part of the stream and water in the surrounding alluvium that is either discharging into the stream or being discharged by the stream. That line is relatively close to the stream bed, with

variations depending on the volume of stream flow and other variables. Thus, if a well is drawing water from the bed of a stream, or from the area immediately adjacent to a stream, and that water is more closely related to the stream than to the surrounding alluvium, as determined by appropriate criteria, the well is directly depleting the stream. If the extent of depletion is measurable, it is appreciable. This is not an all-or-nothing proposition. For example, if the cone of depression of a well has expanded to the point that it intercepts a stream bed, it almost certainly will be pumping subflow. At the same time, however, it may be drawing water from the surrounding alluvium. Thus, part of its production may be appropriable subflow and part of it may not. Even though only a part of its production is appropriable water, that well should be included in the general adjudication."

Moreover, the present court said on page 391,

"To say that all of an alluvial valley's wells may be pumping subflow is at odds with Southwest Cotton's statement that subflow is found within or immediately adjacent to the stream bed."

The sentence quoted is dependent upon the previous sentence which states,

"The record shows, however, that in a given area the younger alluvium may stretch from ridge line to ridge line so that all wells in the valley would be in or near the younger alluvium."

As stated before, every witness found that statement not scientifically supportable. It violates general principles of geology and hydrology. Therefore, this trial court must suggest, based on the evidence before it, that at least some portion of the wells in a valley's alluvium must be pumping "subflow" or their "cones of depression" have reached the "subflow" area. Therefore, they are depleting the surface flow as indicated by the previous quotation on pages 32 and 33 which discusses the surface flow's tendency to fill the loose, porous material of its bed. The only logical and rational way the "Southwest Cotton" and "In re Gila" theories as to "subflow" can be made consistent with the scientific principles testified to is to turn to the tests on page 392 of 175 Ariz. where the Supreme Court itself urged of flow direction, elevation, gradient and chemical composition.

> "Whether a well is pumping subflow does not turn on whether it depletes a stream by some particular amount in a given period of time. As we stated above, it turns on whether the well is pumping water that is more closely associated with the stream than with the surrounding alluvium. For example, comparison of such characteristics as elevation, gradient, and perhaps chemical makeup can be made. Flow direction can be an indicator. If the water flows in the same general direction as the stream, it is more likely related to the stream. On the other hand, if it flows toward or away from the stream, it likely is related to the surrounding alluvium."

If we add to those tests the concept that if a "subflow" zone can be differentiated from adjacent geologic units such as tributary aquifers and the basin-fill aquifer which discharge into it or receive discharge from it, a set of principles can be developed to define "subflow" and still be consistent with "Southwest Cotton" and science.

DEFINING "SUBFLOW"

A. General Principles

The briefs filed, except for that of the Nature Conservancy, take a position of 1) a narrow band defined by the edge of the river principal channel, or 2) a slightly larger post-1880 depositional layer, or 3) the edge of the central valley's younger alluvium. The Nature Conservancy offers two solutions, the first geologic and the second solution provided by the area's natural vegetation, the growth of phreatophytic plants located in the riparian zone. Consideration of all of these proposals does not require an "either/or" solution. Rather, it provides an opportunity to use a building-block method to find proper parameters of the "subflow" zone laterally and vertically. This Court will attempt to do this by going from the narrowest to the widest zone, and for each asking whether it can be a part of a wider zone or does it define the absolute limits of "subflow."

Before discussing the conflict between different sides or proposals, the Court finds that the opinion of "In re Gila" and the evidence which was uncontested requires that any "subflow" zone must be defined by at least the following principles:

1. The "subflow" zone must be adjacent and beneath a perennial or intermittent stream.

2. It may not be adjacent or beneath an ephemeral stream. However, it may be adjacent or beneath an ephemeral section of a perennial or intermittent stream, if the ephemeral section is caused by adjacent surface water diversion or groundwater pumping. There must, however, be a saturated zone beneath connected to similar zones beneath the upper and lower perennial or intermittent stream sections.

3. Except as set forth in paragraph 2 above, there must be a hydraulic connection between the surface stream and the "subflow" zone.

4. The "subflow" zone must be distinguished from adjacent tributary aquifers or connecting basin fill.

5. The parameters of the "subflow" zone, if it is to be defined by reference to the saturated floodplain alluvium, Holocene alluvium, or younger alluvium, must be outside of and not include those tributary alluvial deposits known as "inliers" as indicated in figure 6 of the Stetson Report (exhibit 2).

6. Wells which are located in but perforated below the saturated floodplain alluvium aquifer are to be included in the "subflow" component unless these perforations are proven by their owners to be below a confining zone of impermeable material such as clay as the inevitable "draw-down" of the well must affect the "subflow zone" above the perforation.

7. Wells located outside the lateral parameters of the defined "subflow" zone are not included unless it is proven that their "cones of depression" reach the "subflow" zone and the drawdown from the well affects the volume of surface and "subflow" in such an appreciable amount that it is capable of measurement.

B. <u>Edge of the Principal or Dynamic Channel</u>

The reports of Don Young for the State and William G. Wellendorf for the Town of Mammoth and the Gila Valley Irrigation District (exhibits 5 and 8) propose the narrowest of the "subflow" zones, to wit: the edge of the bed of the principal channel which, interestingly enough, Mr. Wellendorf defines as the "Holocene" channel as contrasted to Dr. Montgomery's "post-1880 entrenchment." Within its banks the low-flow stream meanders back and forth in large figure "S" curves. These banks are defined by the highest flows of one- to three-year flood cycles.

The sole merit of these proposals is the banks or edges of the channel are easily found on aerial photography: "just look for the white sand." He frankly admitted on June 1, 1994 that all he did was use the contour lines on the U.S.G.S. quad maps for the basin and little else. These contour lines bear no relationship to any geologic difference in the formation. Wellendorf's testimony clearly showed a theory of using the most easily found ground feature and then dealing with the real problems of surface water depletion on a case-by-case method by determining the extent of each well's "cone of depression." The problem with any proposal which emphasizes "cone of depression" solutions over finding an adequate "subflow" zone is that the determination of a well's "cone of depression" is a very complicated, difficult and expensive process. This is seen in the confrontational testimony of Montgomery, Ford and Page on how to use the various computer-program techniques and which program is more accurate or useful. All, however, agreed that "cone of depression" analysis is expensive and complicated, and that the assumptions necessary and the frequent lack of data to support such computer techniques reduce the reliability significantly.

Even witness Wellendorf agrees as is seen in this discussion between himself and the Court as reported on pages 64 and 65 of Volume VIII of the hearing transcript:

> "THE COURT: Did you not make this statement on page 6 of your report, the last sentence of the middle paragraph: 'While empirical techniques exist to numerically model this technique, heterogeneities known to exist in aquifers quickly reduce the effectiveness of these techniques.'
>
> I probably mispronounced 'heterogeneities.' Is that correct?
>
> THE WITNESS: Yes.
>
> THE COURT: What in fact you're basically telling us is that the technique of determining cones of depression, particularly when the elevation of the water level is not

flat all the way across but is sloping down to the river and maybe [sic] sloping the other way naturally, is subject to a number of assumptions that make it very difficult.

THE WITNESS: Correct.

THE COURT: So from your standpoint of what you've done, you've given us the narrowest subflow zone and set up the most complex method of determining what we're going to set up in this adjudication, because you are going to have to determine individually whether or not each well has a cone of depression which hits either your subflow zone or the stream flow, isn't that correct?

THE WITNESS: Yes."

Also, witnesses agreed no one with any common sense locates a well in the channel where the flooding expected on a one- to three-year basis can destroy the well's mechanical and electrical functions. Therefore, to utilize a method which would put every single well in the basin outside the "subflow" zone--even where a well sits on the banks of the river 10 to 20 feet from its flow--presents a danger of turning this adjudication into a totally meaningless activity while the river is slowly sucked dry like the Santa Cruz River.

While Mr. Young suggests the vertical limits of his "subflow" zone are the top of the older alluvium or bedrock where no older alluvium exists, Wellendorf's vertical limit is almost impossible to find especially if one looks at his figure 2 exhibit of "Holocene Cross Channel Cross Section and Complete Fining Upward Sequence" (see exhibit 8). He appears to place his vertical bottom at bedrock. The testimony of this hearing indicated deep alluvial and basin-fill deposition. There was no testimony of how far it is to bedrock. The only limit is the HSR use of a 1,200 foot fill to determine the aquifer capacity of 85 million acre feet. The question then must be asked, "Why not the same basis for choosing the lateral limits as those used to choose the vertical limits?" When we note that what these two experts had done was draw a hypothetical line down the middle of the same geological unit, we must realize that their lateral limits have no geological, hydrological or riparian basis.

If that weren't enough, the real problem of this proposal is that the location of today's principal channel boundaries have no stability all as admitted by Mr. Wellendorf on page 78, line 8 to 23:

> "THE COURT: Let me ask you two other questions because of what she brought up. Dr. Montgomery suggested that the principal channel, while probably somewhat stabilized today, has previously had and does still have some meander effect as compared to his theory of post-entrenchment alluvium. Would you agree with that?
>
> THE WITNESS: Yes.
>
> THE COURT: So that the channel is subject to being moved by high floods, high flows and things of that nature.
>
> THE WITNESS: Yes, I think it would take a pretty major event.
>
> THE COURT: Like some of the floods that are mentioned in Hereford's report?
>
> THE WITNESS: Yes."

At the Paul Sale property near Winkelman on March 4, 1994, Mr. Sale explained how the 1983 flood had moved the channel 1,000 feet westward and wiped out 90 acres of his farm land. In 1993 the channel moved once more. This time it ended up 500 feet eastward after it moved westward again and took out 15 additional acres of his pecan orchard. Further, he also pointed out the several locations the principal channel had occupied since he had begun farming there in 1970 and how it had moved after the 1979, 1980, 1983 and 1993 floods.

On the last day of court testimony Steve Erb testified how a comparison of the 1935 aerial photograph to the more recent 1990 aerial photograph showed significant changes in location of the river channel from Pomerene north for several miles (see exhibits 260 and 261). During his cross-examination there was a discussion of an overall review of the 1935 aerial photography and a comparison to the latest 1990 photographs. This was also reviewed in a discussion on our field trip at the beginning of March 4, 1994.

Also in the Hereford report (exhibit 190), page 8, figure 5, there is presented a clear representation of channel migration in a large meander about 2 miles north of the Hereford bridge. It illustrates channel movement of approximately 1,500 feet.

As a result of this, the Court requested that ADWR compare its 1935 aerial photography with its latest 1990 photos along the entire river and report any channel changes found. That report now completed indicates the channel is not stable. It often narrows and shifts significantly. The results of that study, exhibit 365 and Appendix E1 to E3 and the map of the area of the study (Appendix D) are attached. The study shows a single channel widening of up to 168 feet and a narrowing in 27 locations of from 67 feet to 976 feet. It also shows 28 shifts in overall channel location of from 66 feet to 1,200 feet.

Unfortunately none of the 1935 aerial photography was then placed in evidence during the ten-day hearing. The same was true of most of the 1990 aerial photography except for exhibits 260 and 261. This Court, therefore, brought the matter up at its monthly hearing on April 29, 1994 in the following manner as indicated by its minute entry of that date.

> "The Court, while working on the ruling for the trial, recalled the testimony of Steve Erb and the discussion with Mr. Sales regarding the movement of the river at Pomerene during the 1970, 1983 and 1993 floods. The Court requested that ADWR compare the 1935 and 1990 aerial photographs to determine the movement of the channel as well as what happened to the riparian areas along the river. The photos from 1935 are the earliest photos except for some old historical photos found in exhibit 190, the Hereford Report, and the book entitled <u>The Changing Mile</u>. ADWR did 26 transects on the river and found a substantial narrowing of the channel. The widest widening of the channel from 1935 to 1990 was 100 feet; the greatest narrowing was 900 feet. There was only one instance of widening but 25 instances of narrowing and 26 instances of substantial shifts, the largest of which was approximately 1,000 feet. The photographs will be available after the hearing and Chuck Cullom will answer questions from counsel. ADWR will have the materials available for the next 10 days and copies are available. The Court intends to use these studies for its ruling. If counsel wish to contest the results of this study, affidavits may be filed as was done with the rebuttal affidavits at the evidentiary hearing."

Thereafter several parties filed affidavits. Salt River Project filed an Affidavit of Jon Ford who supports the conclusions of ADWR and opines what appears to be a rational reason for the narrowing of the channel to wit: vegetative growth during periods of low water flow, consisting of phreatophytes above the "subflow" zone, attempts to fill in all but the low-flow channel. However, during periods of high flow the erosive force of the floods "clean out" these vegetative obstructions. William G. Wellendorf also filed an Affidavit which basically criticized ADWR's technique of photo interpretation.

Dr. Errol Montgomery also filed an Affidavit which also attempts to critique ADWR's photo comparison method, but basically agrees with ADWR's substantial conclusions that there is substantive evidence of a narrowing of the principal channel from 1935 to 1990 and some shifting of its location. Basically Dr. Montgomery's Affidavit was directed to showing that most, if not all, of these shifts in location and size took place within the boundaries of what he proposes for the "post-1880 entrenchment" and deposition zone.

As the affidavits increased, there was a further request for an evidentiary hearing and the Court agreed to hold such and did on June 14 and 15, 1994.

The hearing produced testimony from Charles Cullom of ADWR who did all of its reports on the comparative aerial photo interpretation, Jon Ford for SRP, William Wellendorf for the Town of Mammoth and Drs. Schumm and Montgomery for the groundwater users.

While all agreed that an attempt to compare early aerial photography (1935) to recent photography (1990) was a difficult scientific process which could not produce exact comparisons, all agreed that experienced analysts could determine important information if carefully done. This Court believes all who testified were very experienced, did a careful job and the results were very important in that it showed:

1. The principal channel in nearly every instance where a comparison could be made was narrowed often significantly between 1935 and 1990.

2. When that narrowing occurred, there was often a shift in location of the whole channel to the east or west. In several instances this shift took it beyond the channel parameters of either Wellendorf, Young, Schumm or Montgomery. See exhibits 260, 261, 313, 317, 319, 320, 324, 325, 328, 330, 331, 332, 333, 334, 335, 338, 339 and 365.

Exhibits 313 and 365 are the latest ADWR calculations of the channel changes on the 28 transects mentioned previously. Exhibit 331 is the calculation made by Errol L. Montgomery and Associates, Inc. from the same aerial photography. The latter two exhibits (365 and 331) are also attached as Appendix E-4 to E-8. In addition to those calculations, this Court made its own comparison of each of the aerial photographs and based on all of the above finds:

CHANNEL MOVEMENT				
TRANSECT LOCATION	CHANNEL SIZE	FEET	DIRECTION OF MOVEMENT	FEET
1a	widen	168'	east	500'
2a	narrowed	207'	west	491'
2b	narrowed	307'	east	656'
2c	narrowed	477'	east	288'
2d	narrowed	104'	east	143'
3a	narrowed	170'	east	449'
3b	narrowed	439'	west	429'
3c	narrowed	398'	east	530'
3d	narrowed	134'	east	107'

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SUPERIOR COURT OF ARIZONA
MARICOPA COUNTY

CLERK OF THE COURT

June 30, 1994 HON. STANLEY Z. GOODFARB K. Abbott
Deputy

№ W-1, W-2, W-3, W-4

In Re The Adjudication of: Continued

CHANNEL MOVEMENT				
TRANSECT LOCATION	CHANNEL SIZE	FEET	DIRECTION OF MOVEMENT	FEET
4a	narrowed	236'	east	190'
4b	narrowed	337'	west	557'
5a	narrowed	100'	west	64'
5b	narrowed	630'	west	541'
5c	narrowed	62'	east	964'
6a	narrowed	134'	west	234'
6b	narrowed	100'	west	1200'
6c	narrowed	0'	west	667'
6d	narrowed	300'	east	466'
7a	narrowed	367'	west	700'
7b	narrowed	200'	east	500'
7c	narrowed	100'	east	100'
7d	narrowed	133'	east	133'
8a	narrowed	966'	west	900'
8b	narrowed	400'	east	366'
8c	narrowed	200'	east	233'
9a	narrowed	500'	east	433'
9b	narrowed	800'	east	500'
9c	narrowed	399'	east	566'

In spite of all of the protestations of Mr. Wellendorf and Dr. Montgomery that, in their opinions, the channel from 1935 to 1990 was "stable," any view of the channel location as shown on these two sets of aerial photographs taken fifty-five years apart shows the invalidity of those opinions.

While the Court clearly finds that the Wellendorf and Young proposal of the principal channel as the extent of the "subflow" zone is without merit, the Court does find that the parameter of that channel does constitute the innermost portion of that zone.

C. <u>"Post-1880 Entrenchment" and Deposition</u>

The principal theory proposed by the "groundwater users" and its supporters is the theory of Drs. Montgomery and Schumm that "subflow" is best defined by use of the lateral limits of what they claim is the post-1880 depositional layer and the vertical limit is the bottom of the Holocene or the top of the basin fill. Unfortunately, neither of their reports filed on December 14, 1993 (exhibits 6 or 7) mentioned this theory. Dr. Montgomery proposed basically the same lateral limits as Dr. Wellendorf and Mr. Young--a smoothed principal channel--and Dr. Schumm proposed nothing as 17 of the 19 pages of his expert report were taken up with his "curriculum vitae." Only two court days before trial, the new theory was revealed in a "Disclosure Statement" which presenters of witnesses including the groundwater users did not have to file. In spite of its late disclosure, the Court permitted the theory to be presented and it still thinks it appropriate because the entrenchment and deposition theory is supported by the work of Richard Hereford (exhibit 190). However, the Hereford Report only discusses a portion of the upper San Pedro basin. There is no mention of the lower basin from Pomerene north. His work probably related to the part of the basin he knew best. A copy of the map of the area in which he worked is attached as Appendix G.

The lower basin is quite different physically and geographically. This was quite evident from the field trip. The lower river valley is much narrower. The gradient of the stream is steeper. There are more areas of thicker vegetation. The mountains and adjacent foothills encroach closer to the river. The Court has attached seven oblique aerial photographs as Appendix H, I, J, K, L, M, and N. The first three are typical views of the upper basin and the last four are typical of the lower basin. The differences between the basins are quite evident in comparing the different sets. With regard to the lower basin, the last four photographs present a fairly clear view of where the basin fill meets the floodplain alluvium and how the riparian vegetation can be used to define the "subflow" zone in some areas.

This Court will not comment on the charges of lack of credibility that the opponents of the groundwater users seem to dwell on because of their late disclosure. This Court assumes that Drs. Montgomery and Schumm became aware of the Hereford Report after their initial investigation and decided that the geologic unit which that report presented made a lot more sense than the edges of a stream channel. This was probably for the same reasons this Court pointed out previously. It was also easier to defend; and one can hardly fault them for that.

Having said that, the Court believes the lack of channel stability discussion previously set forth on pages 39 to 43 of this Order applies equally to Montgomery and Schumm's theory as to Wellendorf and Young's theory of the edge of the principal channel. The "post-1880 entrenchment" and deposition theory is entirely dependent on the deeper entrenchment of the channel after 1880. If that channel lacks stability, it is difficult to understand how the deposition, which takes place after such flooding entrenchment, can have any more stability than the channel it follows. Moreover, if as Hereford suggests, most depositional layers occurred after 1937 while the entrenchment started 50 to 57 years earlier, that geologic unit's lateral stability must be considerably less than that of the Holocene which started after the "Ice Age" and has been in place 10,000 or more years. A post-1937 depositional era, at best, is a minuscule portion of geologic time.

When cross-examined about the lack of channel stability as discussed previously on pages 39 to 43, Dr. Montgomery's position was that such stability problems related only to the physical channel itself and since he relied on the parameters of the "post-1880 entrenchment," the problem did not affect the validity of his opinion. However, after viewing the 1969 infrared aerial photograph of the area north of Benson and past Pomerene, his exhibits 340 and 341, he had to agree that the 1935 channel was significantly different and much of it outside of his defined "post-entrenchment" boundaries from the Benson railroad bridge north to Pomerene and in the Cascabel area.

Much as Drs. Montgomery and Schumm might desire the Court to accept these variations from where they first located this "post-1880 entrenchment" corridor, there are other facts which further erode their "stability" claim for this "post-1880 entrenchment" theory which are as follows:

1. The location of the original dam for the Pomerene Canal was located in Township 17S, Range 20-21E, section 25. It is obvious that the original dam had to be located in the channel of the river as it was the source of the community of Pomerene's irrigation water at that time. However, when the 1921 flood destroyed and moved that dam downstream, it was replaced with a newer dam in section 36 to the southwest. Yet, the Montgomery designation of the "post-1880 entrenchment" defines a different channel and fails to recognize the old channel where the first dam was. (See exhibits 86 and 319.) By measurement it is clear Dr. Montgomery's "post-1880 entrenchment" leaves out at least 4,000 feet of old channel, some of which is 700 to 800 feet east of their designated "post-1880 entrenchment" corridor.

2. Also, in sections 3 and 4 of Township 15S, Range 20E, there is another large area missed in the original designation of exhibit 88. It is now shown on exhibit 320 and was referred to in the testimony of June 14, 1994 as an area of probably an early attempt at an orchard.

3. Another important area of misdesignation is the area of the Paul Sale property, sections 5, 6 and 8 of Township 6S, 12 and 16E. (See exhibit 321 to 325 which are transparencies of the channels boundaries as shown on the 1935, 1947, 1955 and 1990 and most recent evolution after the 1993 floods.) In comparing these exhibits with exhibit 91, the map on which Dr. Montgomery or his associates drew the parameters of the "post-1880 entrenchment" channel, it is clear they missed by nearly 1,000 feet in some places, the east edge of channel in sections 5, 6 and 8 as shown on the 1935 aerial photography.

Attached as Appendix O-1 to O-5 are exhibits 317, 319, 320, 325 and 338 which indicate the misdesignations of the channel in the areas of the Benson railroad bridge to the north, the dam for the Pomerene Canal, Cascabel and the Paul Sale property.

Also, if one examines the exhibits prepared by Dr. Montgomery's firm which are exhibits 332, 333, 334 and 335, and the enlargements of the first three which are exhibits 347, 348 and 349, it is clear that even he agrees that at transects 2a, 2c, 3b, 3c, 3d, 5a, 5b, 5c, 6b, 6c, 6d, 8a, 8b, 8c and 9b the 1935 aerial photography shows the channels of the river as located outside of those parameters of what he calls his "post-1880 entrenchment." Copies of exhibits 332 to 335 are attached as Appendix O-6 through O-9.

Another problem with this "post-1880 entrenchment" theory is the lack of consistency between the lateral and vertical limits of the proposed "subflow" zone as discussed previously. Also, it must be pointed out that with a knowledge that this post-1937 depositional layer has a thickness of from 4 to 13 feet and some of it is "vadose" or non-saturated, we have at best a saturated post-1937 layer of from 0 to 10 feet. In most of the river's length it sits above or is inset in the Holocene layer. Therefore, the Holocene layer below it must be totally saturated for the balance of its 40 to 200 feet of depth. In spite of this, Drs. Montgomery and Schumm as well as Mr. Young propose a vertical limit of "subflow" at the bottom of the Holocene and admit that any well which has perforations below it and in the basin fill will quite quickly draw down water from the Holocene. The water pulled from any "subflow" zone will quickly affect the volume of the surface stream above.

A "subflow" zone defined by this post-1937 depositional layer theory has very few wells located within its lateral limits. This, of course, increases the number of the "cone of depression" analyses which must be made. The problems associated with this analysis have been previously discussed.

At the end of the first 10 days of hearings, Drs. Montgomery and Schumm finally hung their hats on two principal claims:

1. The post-1880 or post-1937 depositional layers are significantly more permeable than the Holocene; and,

2. The Holocene is cemented in a way that bonds the sand, gravel and boulders into a consolidated mass through which less water can pass.

However, the testimony of Dr. Maddock, Steve Erb, Jon Ford, Oliver Page and Allan Gookin are all in direct conflict with those claims. Further, the drill logs of the recent drilling by Ford and Page disprove this theory as did ADWR's interpretation of the ADOT drill logs on the bridges on I-10 at Benson and the Charleston and Lewis Springs bridges. This is also true of other well logs in the area including the well logs of the Magma wells at site number 11 on our field trip 5 miles south of Mammoth (see the rebuttal affidavits of Ford and Page, exhibits B, C and D attached to the Salt River Project Post-Hearing Brief of March 18, 1994 and exhibits 262, 271 and 281 from the trial).

Probably the most confrontational of all the field trip discussions between Drs. Montgomery and Schumm and Jon Ford and Oliver Page occurred on the afternoon of March 4, 1994 at site 11. It was at the southwest corner of the cultivated field and in the river bed adjacent thereto shown on exhibit 78 in evidence and attached as Appendix M. Here Drs. Montgomery and Schumm tried to explain why the field just east of the river and the wells located adjacent thereto were not in the "subflow" zone. This was, they claimed, because the "post-1880 entrenchment" deposits which were only in the sandy areas adjacent to the river, were more permeable and less cemented than the Holocene alluvium which underlay the cultivated fields and large phreatophytic areas of mesquite out of which those fields extracted. A look at the photograph (Appendix M) shows the physical relationships. To the knowledgeable eye it probably shows the edge of the "subflow" zone where the phreatophytes meet the basin fill rather than simply the sandy banks of the river as claimed by Drs. Montgomery and Schumm. Further, in spite of all their claims of new kinds of tests as to permeability and cementational differences between the post-1937 depositional layer and the Holocene it was inset into, three Magma wells drilled in 1991 in this very area and shown in ADWR well log registration records reveal the true underground record when they showed the following:

<u>Well #1</u>, registration #55-529969, drilled 2/26/91
sand, gravel and cobbles from 0 to 45 feet
clay from 45 to 47 feet
sand gravel and cobbles from 47 to 63 feet

<u>Well #2</u>, registration #55-529971, drilled 2/26/91
sand, gravel and clay from 0 - 32 feet
sand, gravel and cobbles from 32 - 65 feet

<u>Well #3</u>, registration #55-530124, drilled 1/28/91 to 2/8/91, to 1000 feet of depth
sand and gravel from 0 - 70 feet

This last well was drilled by Dr. Montgomery's firm. (See the attachments to the Salt River Project Post-Hearing Brief all of which are copies of drill log records filed with ADWR as required by statute.

Obviously, Magma's own well-drilling logs do not support the Montgomery/Schumm theory of higher permeability and less cementation of this post-1937 depositional layer.

In the opinion of the Court, the weight of the evidence clearly fails to indicate any significant difference in permeability between what Drs. Montgomery and Schumm contend is a "post-1880 entrenchment" depositional layer and the balance of the Holocene floodplain alluvium of which it is a part. The Court finds the testimony of Messrs. Erb, Ford, Page and Gookin have the greater weight and the exhibits presented showed no indication of any claimed differences.

It is incongruous for the groundwater users to first claim that there is a great disparity between the lithology, hydraulic conductivity, and other characteristics of the post-entrenchment alluvium and the Holocene, and then advocate that the post-entrenchment alluvium be used only to define the lateral limits of "subflow" with the Holocene to be utilized to set its vertical extent. This is particularly true when the entrenchment is only 5% to 10% of the Holocene depth.

Even Dr. Montgomery's own Report on October 2, 1987 (exhibit 11 of the 1987 hearings) describes the floodplain alluvium of the San Pedro in the following terms:

> "<u>FlOODPLAIN ALLUVIUM</u>
>
> <u>Geologic Feature</u>
>
> Floodplain alluvium occurs along the San Pedro river and its major tributaries.... Records of water wells which penetrate the unit near San Manuel indicate that the thickness of the floodplain alluvial deposits ranges from about 30 to 205 feet. The

> floodplain alluvium is commonly coarse-grained and consists chiefly of non-consolidated sand, gravel, and boulders. (emphasis added)
>
> Groundwater Features
>
> In the Lower San Pedro Basin, the groundwater level commonly occurs above the base of the floodplain alluvial deposits, and the lower parts of the unit are saturated. The deposits are highly permeable, comprise efficient infiltration media, and yield large amounts of groundwater to wells that are completed in the unit. Because the deposits are commonly coarse-grained and non-consolidated, the floodplain alluvial deposits are usually the most permeable of the hydrogeologic units in the basin. The floodplain alluvium accepts and transmits recharge water from streamflow. Groundwater in the unit generally occurs under confined conditions." (emphasis added)

There is no mention therein of any "post-1880 entrenchment" or depositional unit, its high degree of permeability or lack of cementation.

This Court finds the groundwater users theory of limitation of the parameters of the "subflow" zone to be without merit. However, like the principal-channel boundary theory out of which it evolved, the Court believes the lateral bounds of this theoretical unit are within the parameters of a broader "subflow" zone wider than these groundwater users propose.

D. The Nature Conservancy Riparian Zone

The position of the Nature Conservancy is urged by an attorney and hydrologist whose efforts were *pro bono*. It is a pleasure to have such people involved and to be able to largely agree with their position. Their proposed alternatives were:

> "It is clear from all of the evidence that the only reasonably acceptable geologic unit by which subflow may be defined is the holocene alluvium by whatever norm referred to." (p. 2)

> Alteratively they submitted:

> "...it is not necessary to resolve the geologic debate in order to define the subflow zone. Fortunately, nature has already provided readily observable surface indicators of where this underground water is located, those being the phreatophytic plants located in the riparian area or zone immediately adjacent to the river." (p. 5)

If we were limited to only physical evidence of water use at a particular location which had an observable effect on the height of the flow in the stream itself, only the testimony about phreatophytes would meet that test. During our field trip there were anecdotal accounts by Messrs. Lomeli and Smallhouse and Ms. Clark about observable water use by phreatophytes that had a direct, immediate and measurable impact on the surface flow of the adjacent stream. These impacts occurred on a daily or diurnal basis and changes in stream flow were readily observable as were seasonal variations, all relating to the metabolic functions of the plants. The testimony was that the fall and winter seasonal changes could double the stream flow because the leaves were off the trees and there was no transpiration occurring. While daily changes between daylight and dark were not as great, they were clearly discernable. Even Dr. Montgomery agreed when cross-examined by Steven Weatherspoon about a camping experience where the flow was non-existent when he and his son went to sleep, but the stream flowed in the morning because the stream recharged itself at night when the phreatophytes' pumping mechanism was not in effect. No one can be surprised by such facts when the water balance of the San Pedro previously discussed showed that of its total produced supply of 158,610 acre feet, approximately ⅓ or 52,600 acre feet went into phreatophytic use.

The evidence is undisputed that riparian plants directly draw off and diminish the surface flow of adjacent streams. Riparian forestation meets the test of "In re Gila" which asks, "Does the drawing off the surface water tend to diminish appreciably and directly the flow of the surface stream" (p. 393 of 179 Ariz.) Moreover, this Court accepts that we have a readily usable definition of "Riparian Area" in A.R.S. § 45-101(b):

> "'Riparian area' means a geographically delineated area with distinct resource values, that is characterized by deep-rooted plant species that depend on having roots in the water table or its capillary zone and that occurs within or adjacent to a natural perennial or intermittent stream channel or within or adjacent to a lake, pond or marsh bed maintained primarily by natural water sources. Riparian area does not include areas in or adjacent to ephemeral stream channels, artificially created stockponds, man-made storage reservoirs constructed primarily for conservation or regulatory storage, municipal and industrial ponds or man-made water transportation, distribution, off-stream storage and collections systems."

Unfortunately, this Court does not believe that delineation of all riparian areas in their predevelopment stage, as advocated by the Nature Conservancy, will be as easy as it thinks. A look at the 1935 aerial photography of the area does not easily show the boundaries of riparian area in a predevelopment stage. Even then there were large areas of agricultural field development, particularly in the St. David and Pomerene areas. The same is also true in the lower basin where Jack Smallhouse told us his family once farmed 2,000 acres along the river. The field trip in the Hereford and Palominas areas shows fields long cultivated but now unused with limited phreatophyte invasion. Another problem is that in the true predevelopment age before the significant overgrazing of the late 1800s and early 1900s, the heavy grass cover of the upper basin prevented much phreatophication. (See exhibit 190, page 15.) The other side of the coin is that as cultivated fields along the river went out of production, phreatophication increased. (See figures 16 to 19 of exhibit 190.) This is clearly shown by the pictures of the Palominas Bridge taken in 1939 and 1991 which were attached. This shows the problem of phreatophication increases, resultant channel narrowing and later highly erosive effects of flooding when high flows are forced through narrower and narrower channels all as described in the Affidavits of Ford and Wellendorf.

In addition to the study of channel changes and shifts, this Court also requested ADWR to also analyze any change in riparian habitat along the San Pedro River from 1935 to 1990. The study indicated significant riparian changes from reductions of "up to 3,100 feet along one transect to an additional 1,900 feet along another transect." (A copy of that analysis, also a part of exhibit 365, is attached as Appendix F-1, F-2 and F-3.) A study of the 1990 aerial photography shows nearly all reductions to be the result of cultural development such as new agricultural fields.

Figure 5, page 8 of exhibit 190, which is reproduced in Oliver Page's Report for Stetson Engineering in exhibit 2 as its figure 7, and is attached here as Appendix P, shows the lateral migration of this river from 1890 to date in a large meander about 2 miles north of Hereford. Based on our March 4, 1994 field trip, that area is one of many old and new channels. There is nearly a mile of phreatophytic width in this area.

To the extent that phreatophication exists or can be documented in the areas adjacent to the principal channel, it does mark that portion of the area of the "subflow" zone. If it extends to the lateral edge of the saturated floodplain Holocene alluvium, then it is a vital marker. However, even phreatophytes cannot tell the difference between floodplain alluvium and tributary aquifer alluvium and, therefore, can be a false marker. The boundaries of the riparian zones are helpful and certainly within the "subflow" zones if they do not extend over onto the top of tributary aquifer or basin fill. After consideration of flow direction, water level elevation, the gradation of water levels over a stream reach, the chemical composition if available, and lack of hydraulic pressure from tributary aquifer and basin fill recharge which is perpendicular to stream and "subflow" direction, the Court finds the most accurate of all the markers is the edge of the saturated floodplain Holocene alluvium.

E. The Saturated Floodplain Holocene Alluvium

Throughout the hearings, field trip and later briefing, the parties have used the terms Holocene, younger alluvium, and floodplain alluvium interchangeably. This Court believes the proper terminology for the geologic unit which defines "subflow" is the "saturated floodplain Holocene alluvium." That term is used deliberately. Both the Holocene or younger alluvium and the basin fill are descended from the same source, the rock of uplifting mountains. While the depositional processes were somewhat different, where these units meet it is sometimes difficult to discern the differences between one type of eroded, depositional debris from another, particularly when they may both be saturated and water bearing. Moreover, water, when it fills the porosity of a geologic unit, doesn't know the difference between what is "subflow," younger alluvium or basin fill. However, only the younger Holocene alluvium can pass the test of "subflow" as it is the only stable geologic unit which is beneath and adjacent to most rivers and streams, except those in the mountains where bedrock surrounds the flow.

Also, in order to fulfill the definition of "subflow," the geologic unit must be saturated because of the need for a hydraulic connection between the stream and the "subflow." Further definition requires "subflow" to be a part of the surrounding floodplain of the stream basin. Those parts of the alluvial plain which it may be a part of or which it is connected to must be the alluvial plain of a perennial or intermittent stream and not an ephemeral stream or a part of the alluvial plain of a tributary aquifer even if there is an alluvial connection. Where the alluvial plain of tributary aquifers or ephemeral streams connects to the floodplain Holocene alluvium of the stream itself and provides tributary or basin fill recharge, that tributary aquifer must also be excluded because its flow direction is different and often perpendicular to the stream-flow direction.

The evidence here shows that the only true geologic unit which is beneath and adjacent to the stream is the floodplain Holocene alluvium. When it is saturated, that part of the unit qualifies as the "subflow" zone, where the water which makes up the saturation flows substantially in the same direction as the stream, and the effect of any side discharge from tributary aquifers and basin fill is overcome or is negligible. Because low-flow streams like the San Pedro meander back and forth in a series of "S" curves within a wider principal or dynamic channel, flow direction must be the general overall direction of the stream. As Steve Erb testified, as long as the subflow's direction is within 45 degrees of that general stream flow direction, the flow direction requirement is met.

If we add the following additional criteria, then even more certainty and reliability is provided. First, the water level elevation of the "subflow" zone must be relatively the same as the stream flow's elevation. Second, the gradient of these elevations for any reach must be comparable with that of the levels of the stream flow. Third, there must be no significant difference in chemical composition that cannot be explained by some local pollution source which has a limited effect. Fourth, where there are connecting tributary aquifers or floodplain alluvium of ephemeral streams, the boundary of the "subflow" zone must be at least 200 feet inside of that connecting zone so that the hydrostatic pressure effect of the side recharge of this tributary aquifer is negligible and the dominant direction of flow is the stream direction. Fifth, where there is a basin-fill connection between saturated zones of the floodplain Holocene alluvium and a saturated zone of basin fill, the boundary of the "subflow" zone must be 100 feet inside of the connecting zone so that the hydrostatic pressure effect of the basin-fill's side discharge is overcome and the predominant direction of flow of all of the "subflow" zone is the same as the stream's directional flow. The different distances used to overcome the side pressure of the tributary aquifer and basin fill are based on the testimony of Steve Erb given on February 14, 1994 and the different rates of permeability and transmissivity of the different geological units. Appendix Q attached is a copy of exhibit 266 received at trial which represents the best illustration of the relationship of the "subflow" within a reach of floodplain alluvium and basin fill. Appendix R attached shows the relationship of the saturated stream alluvium of the San Pedro and its two tributaries, the Bobocamari and the Aravaipa, to the entire basin of the San Pedro.

The weight of the evidence points to the saturated floodplain Holocene alluvium as the most credible "subflow" zone. Its lateral and vertical limits have existed for some 10,000 or more years. It has far more stability of location than any other proposal including the principal channel which changes approximately every three years, or the post-1880 depositional layer which is really "post-1937" at best, or "post-1955" as indicated in the Hereford Report (exhibit 190 page 8).

It may be true that the surface of the latest layer of deposition resulting from the January 1993 flood is more permeable than the overall permeability of the entire Holocene. But, as Ford, Page, Gookin and Erb testified, and all the drill log results show, there is no significant difference in permeability between the post-1937 layer and the balance of the Holocene. Even the claims by the groundwater users of cementation in the Holocene do not stand up. Not a single drill log supports it. All the claims of the use of the wrong drilling bit do not support it. Even Dr. Montgomery's Report of October 2, 1987 refutes it. While there may be some evidence of cementation in certain layers, there is no evidence it is unit-wide, or that it makes any significant difference in permeability or transmissivity. Therefore, regardless of claims to the contrary, the weight of this evidence supports the saturated floodplain Holocene alluvium as the "subflow" zone.

"CONES OF DEPRESSION"

"In re Gila," page 391 of 175 Ariz., describes a "cone of depression" as the "funnel-shaped area around a well, where the water table has been lowered by the withdrawal of groundwater through the well." That clinical description of a "cone of depression" tells us little of the destructive ability of wells upon basin and range streams in a desert or semi-desert environment such as the Santa Cruz River and the San Pedro River.

On February 1, 1994 Dr. Maddock discussed the "cone of depression" in the Sierra Vista area. He referred to it as "notorious." His computer modeling predicted that 37% of the water which comes from the well systems which serve the area comes out of the San Pedro which is either in the stream or on the way to the stream. He estimated the latter portion to be 1%. Exhibit 163 in evidence is his illustration of how the "cone of depression" in that area has grown since 1968. It clearly shows and the testimony was that the "cone" is in excess of five miles. A copy of Dr. Maddock's exhibit is attached as Appendix S. In his opinion, the "cone of depression" has clearly intersected the stream.

Mr. Erb testified on February 15 that the Tenneco agricultural wells, shown on exhibit 271 in evidence, which location runs from the border twenty miles north, were shut down in the mid-1980s when Tenneco sold its holdings to the BLM for the creation of the San Pedro River National Conservation Area. The drawdown of these wells had turned some parts of the river in this area from perennial to intermittent, and some sections were even ephemeral. After more than eight years of shut down, only one mile of the river is now more perennial than before. On our field trip, however, we found no ephemeral sections and all were at least intermittent. Local residents explain that the large January 1993 flood created large basin-wide recharge and the higher flows observed may be the result of that recharge. A copy of exhibit 271 is attached as Appendix T showing the relationships of the wells in the area to the river. The wells adjacent to the areas of discontinued irrigation are the former Tenneco wells.

What these facts show is that "cones of depression" have long-term effects even after the wells are shut down. Two recent Colorado cases make that clear. Danielson v. Castle Meadows, 791 P.2d 1106 (Colo. 1990) and State Engineer v. Castle 6 Meadows, 856, P.2d 406 (Colo. 1993) discuss the long-term effect of post-pumping depletion. In the "Danielson" case the trial court had found that post-pumping depletions could continue up to and after 200 years. In the remanded trial which took place in 1991, the trial court found the post-pumping depletions could continue up to and after 400 years. In both cases the Colorado Supreme Court found that these post-pumping depletions had to be remedied by the pumps to protect surface water users under COLO. REV. STAT. § 37-90-137(9)(c). In Colorado, augmentation plans, which are approved by the water decree, are used to remedy possible harm to other appropriations.

All of the principal witnesses agreed that even wells located outside of a stream's "subflow" could, over time, build up extensive "cones of depression" which could severely affect the volume of stream flow and the "subflow" which supported it. Even Dr. Montgomery agreed the Santa Cruz was a dead river except where Nogales' effluent created some perennial but polluted flow. This, all agreed, was the result of overpumping, often outside of anyone's "subflow" parameters. Often those wells had extensive and interconnecting "cones of depression." Appendix U, V, W, X, Y and Z attached, are copies of diagrams from exhibit 1 received in evidence at trial and illustrate the effects of "cones of depression."

In the "In re Gila" opinion only one paragraph relates to "cones of depression." It is worth repeating:

> "For example, if the cone of depression of a well has expanded to the point that it intercepts a stream bed, it almost certainly will be pumping subflow. At the same time, however, it may be drawing water from the surrounding alluvium. Thus, part of its production may be appropriable subflow and part of it may not. Even though only a part of its production is appropriable water, that well should be included in the general adjudication." (p. 391 of 175 Ariz.) (emphasis supplied)

The testimony seemed unanimous that consistent with the Supreme Court's pronouncement, if a "cone of depression" of a well intercepts what is eventually defined as the "subflow" zone, then at least some percentage of the water discharged by the well is water subject to the adjudication. As Montgomery admitted, stream depletion occurs as soon as the "cone of depression" reaches the stream, even though it may be some time before the hydraulic gradient at the river is reversed, and may be many years before a particle travels from the stream to the well. See Tr. VI at 14, 49-50. Ford and Page contend that streamflow depletion first takes place when the cone intersects the stream, not when the hydraulic gradient is reversed or the molecule of streamflow is ejected by the well. Tr. I at 47 (Ford); Tr. II at 182 (Page). It is beyond dispute that even before the gradient is reversed, a measurable drawdown at the stream's "subflow" zone necessarily results in water leaving the zone in order to fill the void which has been created by the well. Ford's Report, exhibit 1, at 51 [when the cone intersects the "subflow" zone, it "induce[s] subflow to leave (deplete the Subflow Zone and the stream")]. This is true even where the gradient has not been reversed everywhere between the well and the stream. (Ford's Report at 63-67, especially Fig. 9.3 and Table 9.3)

The groundwater pumpers' position cannot be reconciled with the Supreme Court's unequivocal conclusion that when a "cone of depression" is intersecting the stream bed, it "almost certainly" is "pumping subflow." Apart from their molecule and gradient arguments, no serious opposition has been offered to the approach which was proposed by Ford or Page for handling wells located outside the "subflow" zone. In fact, there appears to be substantial agreement on most points.

For example, Montgomery agreed with Ford that various analytical or modeling methods are appropriate to calculate "cones of depression." Tr. I at 52 (Ford); Ford's Report at 3, 51, C-1 - C-7; Tr. IV at 18-19 and Tr. VI at 13 (Montgomery). Similarly, Ford and Montgomery agree that the calculation of the cone should be based upon the well's entire history of pumping. Tr. I at 52, 54-57 (Ford): Tr. VI at 128-29 (Montgomery). They also agreed that individual analysis of wells is the most appropriate method to compute drawdown at the "subflow" zone. Tr. I at 85 (Ford); Ford's Report, p. 37; Tr. VI at 24 (Montgomery). How this is to be done must be left to the discretion of ADWR as this Court finds there was not testimony of how technically certain determinations were to be made scientifically.

While Salt River Project proposes that a drawdown of 0.1 foot be used for purposes of calculating the "cone of depression," this Court believes such close measurements are difficult, at best, in the field. Rather, it believes that whatever test ADWR finds is realistically adaptable to the field and whatever method is the least expensive and delay-causing, yet provides a high degree of reliability, should be acceptable. While several of the experts arrived at different conclusions, Ford, Page, Montgomery, Erb and Stephenson all testified to a degree that the Court feels assured that scientific method is available to determine below-ground saturation, water level, elevation, gradient, flow direction and extent of "cones of depression."

The Court finds, subject to any *de minimis* standard later to be adopted by the Court, that any well located outside the "subflow" zone that now pumps any percentage of water either from the stream itself or its "subflow" zone, should be included in the adjudication and the total amount of water withdrawn subjected to this proceeding. If we wait until actual water molecules from the San Pedro River are discharged from the many wells which surround it but are not in the "subflow" zone, there may not be sufficient stream flow left to justify this entire adjudication.

PRESUMPTION AND BURDEN OF PROOF

"In re Gila" on page 392 of 179 Ariz. says:

> "If DWR uses the proper test and relies on appropriate criteria for determining whether a well meets the test, its determination that a well is pumping appropriable subflow constitutes clear and convincing evidence. It is consistent with Arizona law, then, to require the well owner to come forward with evidence that DWR is wrong."

This Court agrees that the entire process of the adjudication requires that the independent evaluations of ADWR are entitled to a presumption in their favor and the property owner or an objector to a claim supported by an HSR has the duty to come forward with evidence to overcome that presumption. However, there are questions in the mind of this Court after hearing long periods of evidence over the last fourteen years. They are whether the quality of geologic or hydrologic opinion, the frequent lack of data, and the many assumptions which cannot be fully proven support a requirement that the property owner or objectors should have to overcome a clear and convincing level of burden of proof. Every expert who has attempted to develop opinions as to "cones of depression" often relies on assumptions which are not provable or are only partially provable. The conflicts between Montgomery, Schumm, Ford, Page and Erb in that specific area raise real concern as to the fairness of raising the evidentiary level of burden of proof to clear and convincing for a property owner or objector to overcome a DWR opinion in an HSR. Even if we eliminate many of our *pro per* claimants with a proper *de minimis* rule, this is probably too formidable a barrier for the remainder of those *pro per* parties. It is often too much for represented parties of modest wealth. Only when we get to parties such as the mines, United States, Salt River Project, the State of Arizona and cities of major size are there sufficient assets to fund such evidentiary battles. At least in the area of "cones of depression" a burden of proof of preponderance seems fairer. The same is probably also true in the area of a "subflow" zone determination.

CONCLUSION

The issues here are geologically, hydrologically and factually complex. While courts often deal with complex issues, reviewing appellate courts sometimes are unable to glean from the briefs little more than a summary of the complex evidentiary background and the scientific principles which led to the trial court's decision. To overcome this limitation in this proceeding, this Court believes it has a duty to provide as much detail as it can to explain the factual decisions made, the scientific principles relied on, as well as to provide copies of many of the exhibits considered. It has done that here.

Finally, the length and complexity of this decision requires a summarization of the Court's findings as to "subflow" and dealing with "cones of depression."

1. A "subflow" zone is adjacent and beneath a perennial or intermittent stream and not an ephemeral stream.

2. There must be a hydraulic connection to the stream from the saturated "subflow" zone.

3. Even though there may be a hydraulic connection between the stream and its floodplain alluvium to an adjacent tributary aquifer or basin-fill aquifer, neither of the latter two or any part of them may be part of the "subflow" zone.

4. That part of the floodplain alluvium which qualifies as a "subflow," beneath and adjacent to the stream, must be that part of the geologic unit where the flow direction, the water level elevations, the gradations of the water level elevations and the chemical composition of the water in that particular reach of the stream are substantially the same as the water level, elevation and gradient of the stream.

5. That part of the floodplain alluvium which qualifies as a "subflow" zone must also be where the pressure of side recharge from adjacent tributary aquifers or basin fill is so reduced that it has no significant effect on the flow direction of the floodplain alluvium. (i.e., a 200-foot setback from connecting tributary aquifers and a 100-foot setback from the basin-fill deposits).

6. Riparian vegetation may be useful in marking the lateral limits of the "subflow" zone particularly where there is observable seasonal and/or diurnal variations in stream flow caused by transpiration. However, riparian vegetation on alluvium of a tributary aquifer or basin fill cannot extend the limits of the "subflow" zone outside of the lateral limits of the saturated floodplain Holocene alluvium.

7. All wells located in the lateral limits of the "subflow" zone are subject to the jurisdiction of this adjudication no matter how deep or where these perforations are located. However, if the well owners prove that perforations are below an impervious formation which preclude "drawdown" from the floodplain alluvium, then that well will be treated as outside the "subflow" zone.

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SUPERIOR COURT OF ARIZONA
MARICOPA COUNTY

CLERK OF THE COURT

June 30, 1994 HON. STANLEY Z. GOODFARB K. Abbott
Deputy

№ W-1, W-2, W-3, W-4

In Re The Adjudication of: Continued

8. No well located outside the lateral limits of the "subflow" zone will be included in the jurisdiction of the adjudication unless the "cone of depression" caused by its pumping has now extended to a point where it reaches an adjacent "subflow" zone, and by continual pumping will cause a loss of such "subflow" as to affect the quantity of the stream.

Dated this 30th day of June, 1994.

Stanley Z Goodfarb

Hon. Stanley ~~Z.~~ Goodfarb

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Within an aquifer, the types of material and the geologic and chemical history determine the number of pores and open spaces that will exist. When saturated, these voids determine the volume of water and that will be held in storage within the aquifer. However, not all of the water that is stored within an aquifer is free to be released from storage. Some water is retained in the voids by molecular attraction. The amount that will actually be released is of more concern from a water supply standpoint than the total volume held. The total volume of recoverable groundwater held in storage in the regional aquifer within the San Pedro River watershed to a depth of 1,200 feet below the land surface is estimated to be approximately 83.5 million acre-feet. Table 2-1 breaks this value down by subwatershed. The volume of storage is based on estimated basin fill surface areas, derived form geographic information, average depths of the basin fill alluvium, and average specific yield estimates derived from literature. APPENDIX A describes further the methodology used in calculating storage estimates.

TABLE 2-1

RECOVERABLE GROUNDWATER HELD IN REGIONAL AQUIFER STORAGE
SAN PEDRO RIVER WATERSHED

SUBWATERSHED	GROUNDWATER IN STORAGE (IN MILLION ACRE-FEET)
Sierra Vista	31.8
Benson	27.1
Redington	13.0
Aravaipa	6.2
Winkelman	5.4
Total	83.5

TABLE 4-12

WATER BUDGET ANALYSIS OF THE SAN PEDRO RIVER WATERSHED
1990 DEVELOPMENT CONDITIONS
(ACRE-FEET PER YEAR) (1)

	MEXICO	SIERRA VISTA	BENSON	REDINGTON	WINKELMAN	ARAVAIPA	TOTAL (2)
SUPPLY (+)							
SW Inflow	-	23,420	39,200	25,500	32,100	0	23,420 (3)
GW Inflow	-	3,000	0	120	150	0	3,000 (4)
Tributary SW	35,900	17,300	11,800	15,710	34,070 (5)	1,500	78,880 (6)
GW Recharge	- (7)	13,860	11,760	20,350	9,650	-	55,620 (8)
Imports	-	200 (9)	0	310 (10)	0	0	510
Exports	-	-960 (11)	0	0	-1,860 (12)	0	-2,820
TOTAL	35,900	56,820	62,760	61,990	74,110	1,500	158,610 (13)
WATER USE (-)							
Cultural							
Irrigation	5,000	4,590	14,230	8,480	3,360	1,810	30,660
Domestic	300	460	260	130	170	30	1,020
Municipal	2,300	4,530	750	1,220 (14)	10	0	6,510
Stockpond	1,000	1,460	870	780	160	600	3,270
Reservoirs	-	160	270	80	110	100	620
Mining	3,000	-	0	19,560	0	0	19,560
Industrial	100	50	380	30	0	0	460
TOTAL	11,700	11,250	16,760	30,280	3,810	2,540	62,100
Natural							
Channel Evap	-	950	770	2,220	1,680	970	5,620
Phreatophytes	-	14,450	17,690	13,400	7,060	1,500	52,600
TOTAL	11,700	15,400	18,460	15,620	8,740	2,470	58,220
TOTAL USE		26,650	35,220	45,900	12,550	5,010	120,320 (15)
SURPLUS (=)							
GW Outflow	900	0	120	150	1,570	800	1,570 (16)
SW Outflow	23,420	39,200	25,500	32,100	56,540 (17)	27,559 (18)	56,540 (19)
Change in storage	-120	-9,030	1,920	-16,160	3,450	-	-19,820 (20)

See continuation table for explanation of footnotes.

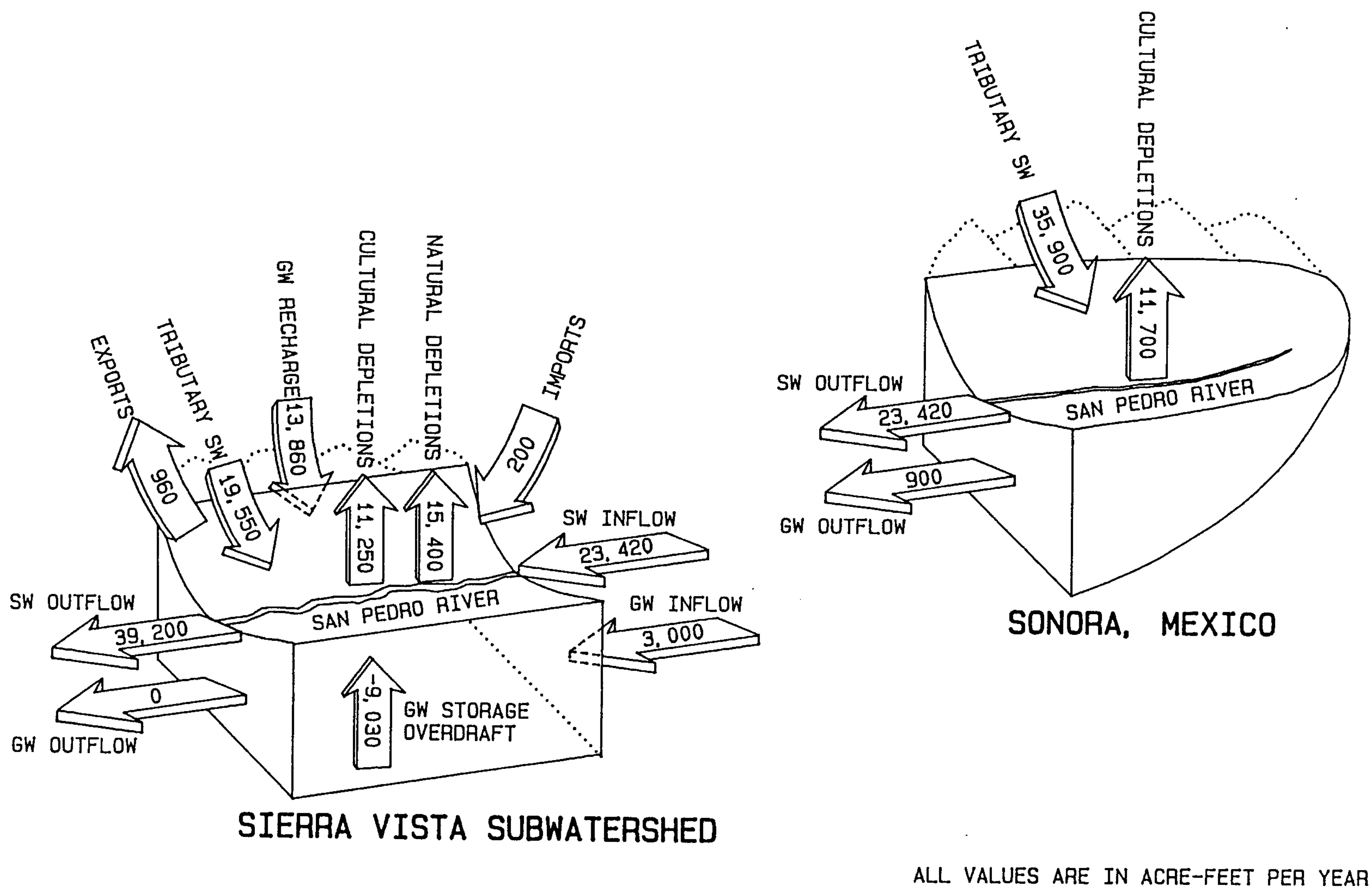


Figure 4-24. Schematic of the water budget components as they relate to the Mexico and Sierra Vista subwatershed portions of the San Pedro River watershed

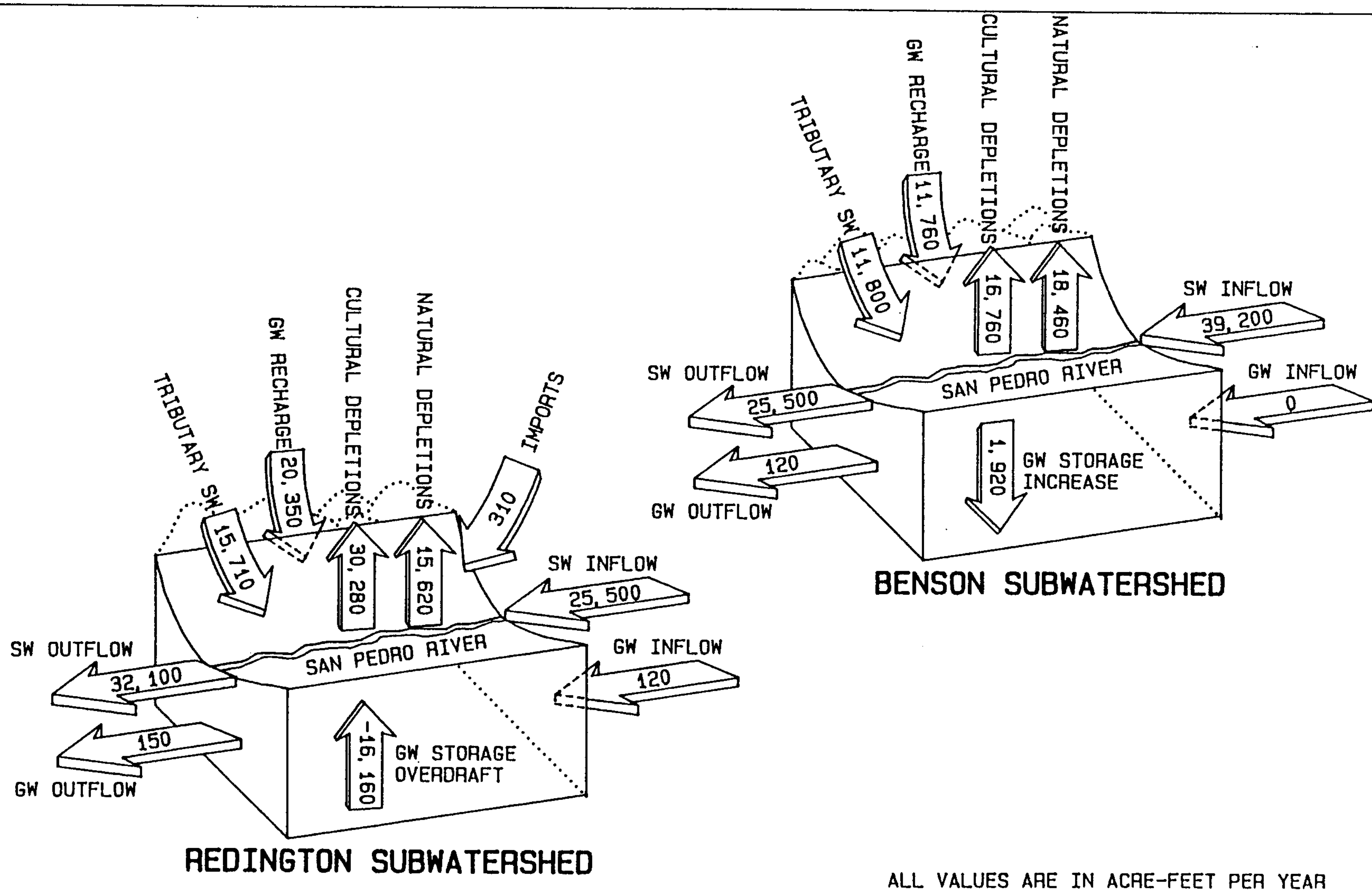


Figure 4-25. Schematic of the water budget components as they relate to the Benson and Redington subwatersheds of the San Pedro River watershed

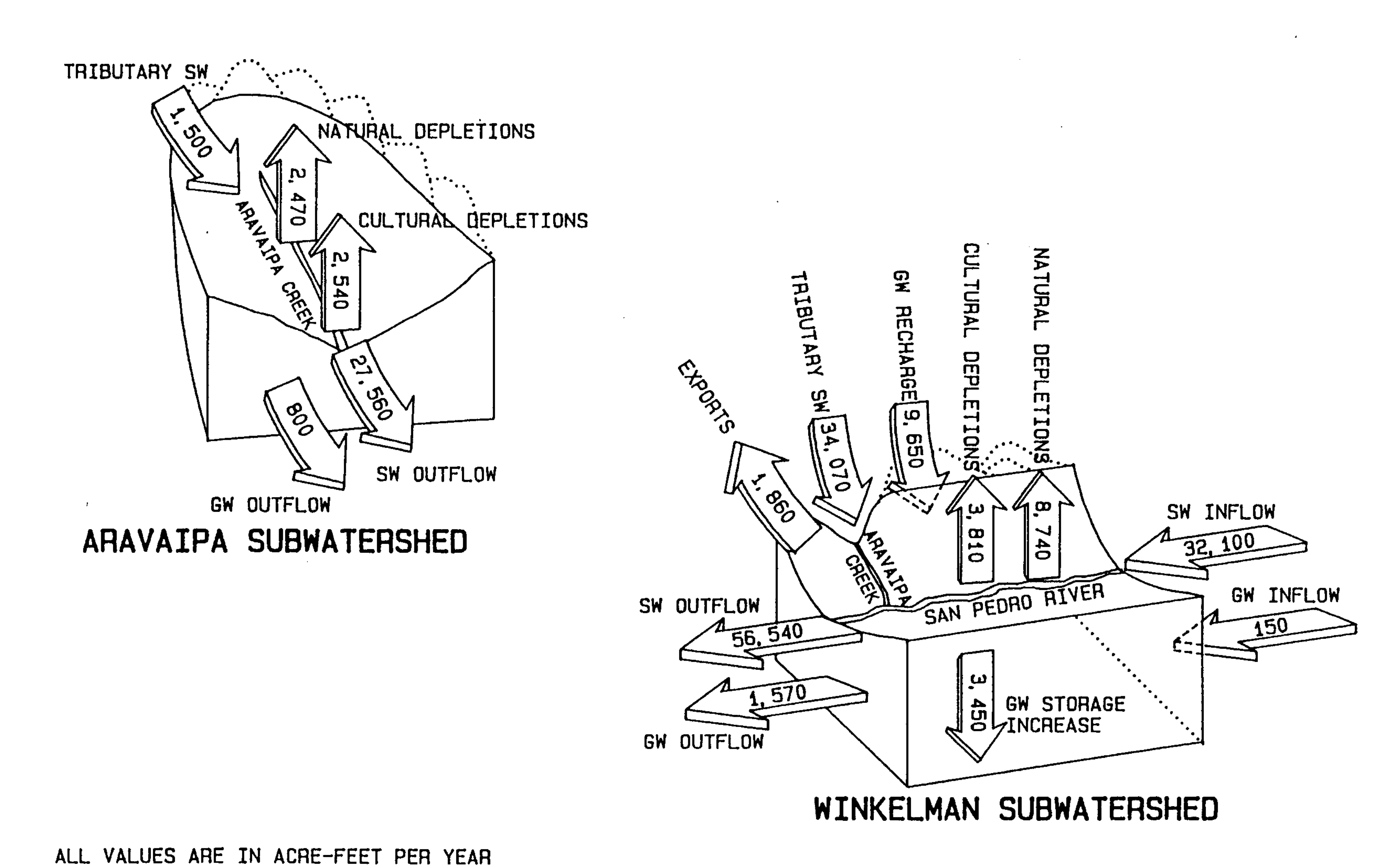
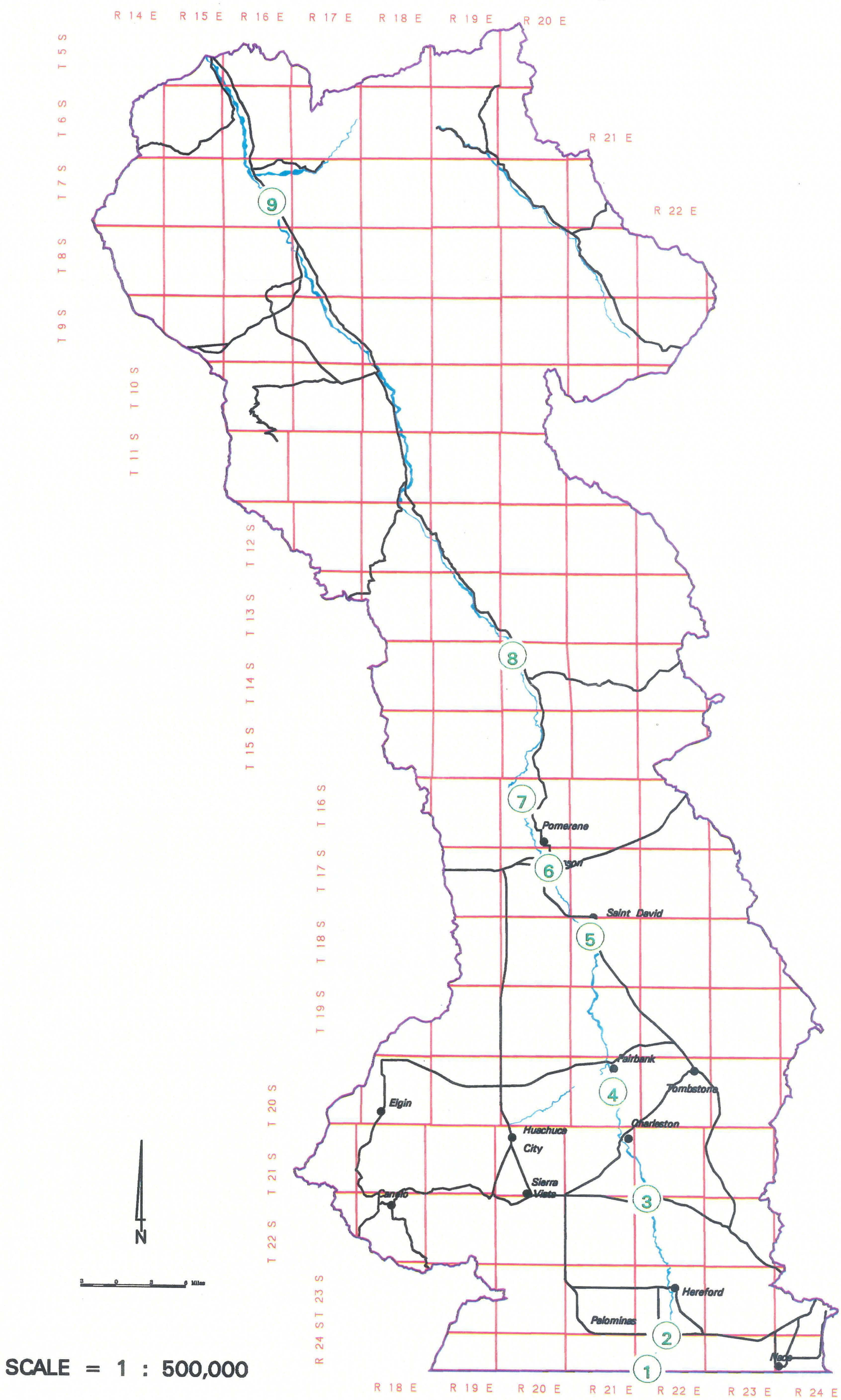


Figure 4-26. Schematic of the water budget components as they relate to the Aravaipa and Winkelman subwatersheds of the San Pedro River watershed

San Pedro Watershed Study Transects



SCALE = 1 : 500,000

Appendix D.

DWR analysis of San Pedro River channel changes from 1935 to 1990.

DWR analyzed the historical aerial photography data base of selected areas of the San Pedro River watershed to document channel change. Channel change was of two types, channel shift (avulsion) and channel narrowing. The channel shifts range from 0 to approximately 1,200 feet as shown in the following table. Channel narrowing ranges from -170 (widening) to 970 feet. The channel was defined for this study as the "sandy wash" described by Dr. Montgomery. The following tables describe the results of the analysis.

The assessment was conducted by locating identical physical or cultural points on the east and west side of the San Pedro River on the 1990 and 1935 photography. A transect line was then drawn to connect the points on each photo. The distance from each point to the "sandy wash" as well as the width of the wash was measured. The difference in width of the "sandy wash" defines narrowing and is rounded to the nearest 10 ft. The shift is defined by the maximum difference in distance from the point to the wash on each side of the wash. The shift is the absolute value of the maximum distance and is rounded to the nearest 100 ft.

Photo 1 - Hereford SW (Mexico to Palominas)[1]		
Transect	Narrowing	Shift
1a	-170	500

Photo 2 - Hereford (Palominas to Lewis Spring)[1]		
Transect	Narrowing	Shift
2a	210	500
2b	310	700
2c	480	300
2d	100	100

Photo 3 - Lewis Spring (Lewis Spring to Charleston)[1]		
Transect	Narrowing	Shift
3a	170	400
3b	440	400
3c	400	500
3d	130	100

Photo 4 - Fairbank (Charleston to Fairbank)[1]		
Transect	Narrowing	Shift
4a	240	200
4b	340	600

Photo 5 - Land (Fairbank to St. David)[1]		
Transect	Narrowing	Shift
5a	100	100
5b	630	500
5c	70	1,000

Photo 6 - Benson (St. David to Pomerene)[1]		
Transect	Narrowing	Shift
6a	130	200
6b	100	1,200
6c	0	700
6d	300	500

Photo 7 - Galleta Flats East (Pomerene to Narrows)[1]		
Transect	Narrowing	Shift
7a	370	700
7b	200	500
7c	100	100
7d	130	100

Photo 8 - Wildhorse Mnt[1]		
Transect	Narrowing	Shift
8a	970	900
8b	400	400
8c	200	300

Photo 9 - Clark Ranch (Mammoth area)[1]		
Transect	Narrowing	Shift
9a	500	400
9b	800	500
9c	400	600

[1] all values in feet

Paul L. Sale Property Channel Shift approximately 950 feet as determined from previous mapping and communication with the property owner.

DWR San Pedro River Study Transects - Channel Change
TRANSECTS (values in feet)

1a	West	Channel	East	TOTAL	%
1935	1000	366	3000	4366	
1990	1332	534	2500	4366	100.0
Difference	332	-168	-500		

2a	West	Channel	East	TOTAL	%
1935	2571	372	3315	6258	
1990	2284	165	3806	6255	100.0
Difference	287	207	-491		

2b	West	Channel	East	TOTAL	%
1935	4432	472	3518	8422	
1990	5088	165	3111	8364	100.7
Difference	-656	307	407		

2c	West	Channel	East	TOTAL	%
1935	6428	609	3789	10826	
1990	6675	132	4077	10884	99.5
Difference	-247	477	-288		

2d	West	Channel	East	TOTAL	%
1935	4296	203	3518	8017	
1990	4439	99	3452	7990	100.3
Difference	-143	104	66		

3a	West	Channel	East	TOTAL	%
1935	7605	303	5276	13184	
1990	7302	133	5725	13160	100.2
Difference	303	170	-449		

3b	West	Channel	East	TOTAL	%
1935	7437	505	4812	12754	
1990	7866	66	4647	12579	101.4
Difference	-429	439	165		

3c	West	Channel	East	TOTAL	%
1935	4609	572	706	5887	
1990	5139	174	937	6250	94.2
Difference	-530	398	-231		

3d	West	Channel	East	TOTAL	%
1935	908	269	2086	3263	
1990	1012	135	2193	3340	97.7
Difference	-104	134	-107		

4a	West	Channel	East	TOTAL	%
1935	1282	337	4487	6106	
1990	1448	101	4677	6226	98.1
Difference	-166	236	-190		

4b	West	Channel	East	TOTAL	%
1935	4352	472	5196	10020	
1990	4230	135	5753	10118	99.0
Difference	122	337	-557		

5a	West	Channel	East	TOTAL	%
1935	3517	469	2814	6800	
1990	3453	369	2850	6672	101.9
Difference	64	100	-36		

5b	West	Channel	East	TOTAL	%
1935	737	837	1234	2808	
1990	737	207	1775	2719	103.3
Difference	0	630	-541		

5c	West	Channel	East	TOTAL	%
1935	469	569	4421	5459	
1990	1150	502	3457	5109	106.9
Difference	-681	67	964		

6a	West	Channel	East	TOTAL	%
1935	2066	267	2166	4499	
1990	1965	133	2400	4498	100.0
Difference	101	134	-234		

6b	West	Channel	East	TOTAL	%
1935	3633	333	800	4766	
1990	2533	233	2000	4766	100.0
Difference	1100	100	-1200		

6c	West	Channel	East	TOTAL	%

1935	5500	233	1533	7266	
1990	5684	233	2200	8117	89.5
Difference	-184	0	-667		

6d	West	Channel	East	TOTAL	%
1935	1200	367	4167	5734	
1990	1666	67	4000	5733	100.0
Difference	-466	300	167		

7a	West	Channel	East	TOTAL	%
1935	3733	500	2233	6466	
1990	3065	133	2933	6131	105.5
Difference	668	367	-700		

7b	West	Channel	East	TOTAL	%
1935	4833	667	5666	11166	
1990	5333	467	5366	11166	100.0
Difference	-500	200	300		

7c	West	Channel	East	TOTAL	%
1935	5633	200	3833	9666	
1990	5733	100	3833	9666	100.0
Difference	-100	100	0		

7d	West	Channel	East	TOTAL	%
1935	4300	266	666	5232	
1990	4433	133	666	5232	100.0
Difference	-133	133	0		

8a	West	Channel	East	TOTAL	%
1935	1267	1133	3833	6233	
1990	1067	167	4733	5967	104.5
Difference	200	966	-900		

8b	West	Channel	East	TOTAL	%
1935	1567	500	2667	4734	
1990	1933	100	2900	4933	96.0
Difference	-366	400	-233		

8c	West	Channel	East	TOTAL	%
1935	3267	400	2900	6567	
1990	3600	200	2667	6467	101.5

Difference	-333	200	233			

9a	West	Channel	East	TOTAL	%
1935	733	767	1500	3000	
1990	1166	267	1567	3000	100.0
Difference	-433	500	-67		

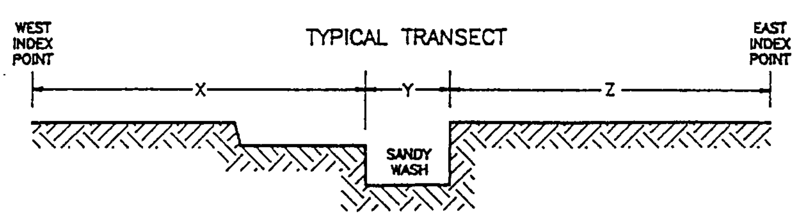
9b	West	Channel	East	TOTAL	%
1935	500	1566	2200	4266	
1990	1000	766	2500	4266	100.0
Difference	-500	800	-300		

9c	West	Channel	East	TOTAL	%
1935	667	1066	3667	5400	
1990	1233	667	3500	5400	100.0
Difference	-566	399	167		
				AVG	100.0

TABLE OF REPORTED DISTANCES ALONG 28 TRANSECTS
IDENTIFIED BY ARIZONA DEPARTMENT OF WATER RESOURCES
FROM 1935 AND 1990 AERIAL PHOTOGRAPHS
OF THE SAN PEDRO RIVER

TRANSECT IDENTIFIER	1935 DISTANCES (feet)*				1990 DISTANCES (feet)			
	X	Y	Z	TOTAL	X	Y	Z	TOTAL
1a	1,000	366	3,000	4,366	1,332	534	2,500	4,366
2a	2,571	372	3,315	6,258	2,284	165	3,806	6,255
2b	4,432	304	3,518	8,254	4,666	165	3,111	7,942
2c	6,428	609	3,789	10,826	6,675	132	4,077	10,884
2d	4,296	203	3,518	8,017	4,439	99	3,452	7,990
3a	7,605	303	5,216	13,124	7,302	133	5,742	13,177
3b	7,437	505	4,812	12,754	7,866	66	4,647	12,579
3c	4,543	572	673	5,788	5,139	174	937	6,250
3d	908	269	2,086	3,263	1,012	135	2,193	3,340
4a	1,282	337	4,487	6,106	1,447	101	4,677	6,225
4b	4,352	472	5,196	10,020	4,230	135	5,753	10,118
5a	3,517	469	2,814	6,800	3,453	369	2,850	6,672
5b	737	837	1,239	2,813	737	270	1,775	2,782
5c	469	569	4,421	5,459	1,072	502	3,751	5,325
6a	2,066	267	2,166	4,499	1,965	133	2,400	4,498
6b	3,633	333	800	4,766	2,533	233	2,000	4,766
6c	5,500	233	2,533	8,266	5,833	233	2,200	8,266
6d	1,200	367	4,166	5,733	1,666	67	4,000	5,733
7a	3,733	500	2,233	6,466	3,065	133	2,933	6,131
7b	4,833	667	5,666	11,166	5,333	467	5,366	11,166
7c	5,633	200	3,833	9,666	5,733	100	3,833	9,666
7d	4,300	266	666	5,232	4,433	133	666	5,232
8a	1,267	1,133	3,833	6,233	1,067	167	4,733	5,967
8b	1,867	500	2,667	5,034	1,933	100	2,900	4,933
8c	3,267	400	2,900	6,567	3,600	200	2,667	6,467
9a	733	767	1,500	3,000	1,166	267	1,567	3,000
9b	500	1,566	2,200	4,266	1,000	766	2,500	4,266
9c	667	1,066	3,667	5,400	1,233	667	3,500	5,400

* Distances "X", "Y", and "Z" are from ADWR overlays for 1935 and 1990 aerial photographs of the San Pedro River. Distance "X" is from an index point at the west end of transect to west bank of "Sandy Wash"; distance "Y" is width of "Sandy Wash"; and distance "Z" is from east bank of "Sandy Wash" to an index point at the east end of transect.



954\F\TRANSCT2.TAB\06-02-94

Appendix E-8
Exhibit 331

DWR analysis of change in riparian habitat along the San Pedro River from 1935 to 1990.

DWR analyzed the historical aerial photography data base of selected areas of the San Pedro River watershed to document change in the extent of riparian vegetation. The change in riparian vegetation along the San Pedro River channel varies widely across the watershed. The magnitude of change is shown in feet along a study transect. The changes are summarized in the following tables.

DWR used the same general methods as outlined for channel changes. The amount of riparian change is defined as the sum of riparian change on the west and east sides of the wash. The riparian change was calculated by subtracting the riparian distance on the 1990 photos from the riparian distance on the 1935 photos. All values are rounded to the nearest 100 feet.

Photo 1 - Hereford SW (Mexico to Palominas)[1]	
Transect	Riparian Change
1a	+100 ft

Photo 2 - Hereford (Palominas to Lewis Spring)[1]	
Transect	Riparian Change
2a	+500 ft
2b	-300 ft
2c	no change 0
2d	no change 0

Photo 3 - Lewis Spring (Lewis Spring to Charleston)[1]	
Transect	Riparian Change
3a	-300 ft
3b	+200 ft
3c	-100 ft
3d	-200 ft

Photo 4 - Fairbank (Charleston to Fairbank)[1]	
Transect	Riparian Change
4a	-100 ft
4b	-500 ft

Photo 5 - Land (Fairbank to St. David)[1]	
Transect	Riparian Change
5a	-1900 ft
5b	no change 0 ft
5c	-200 ft

Photo 6 - Benson (St. David to Pomerene)[1]	
Transect	Riparian Change
6a	+800 ft
6b	+800 ft
6c	+200 ft
6d	-200 ft

Photo 7 - Galleta Flats East (Pomerene to Narrows)[1]	
Transect	Riparian Change
7a	no change 0 ft
7b	+600 ft
7c	-300 ft
7d	-500 ft

Photo 8 - Wildhorse Mnt[1]	
Transect	Riparian Change
8a	+3100 ft
8b	+1800 ft
8c	+1900 ft

Photo 9 - Clark Ranch (Mammoth area)[1]	
Transect	Riparian Change
9a	-500 ft
9b	+700 ft
9c	-500 ft

Copy of the foregoing report
mailed this _____ day of
June, 1994, to all persons
on the Court approved mailing
list dated June 6, 1994

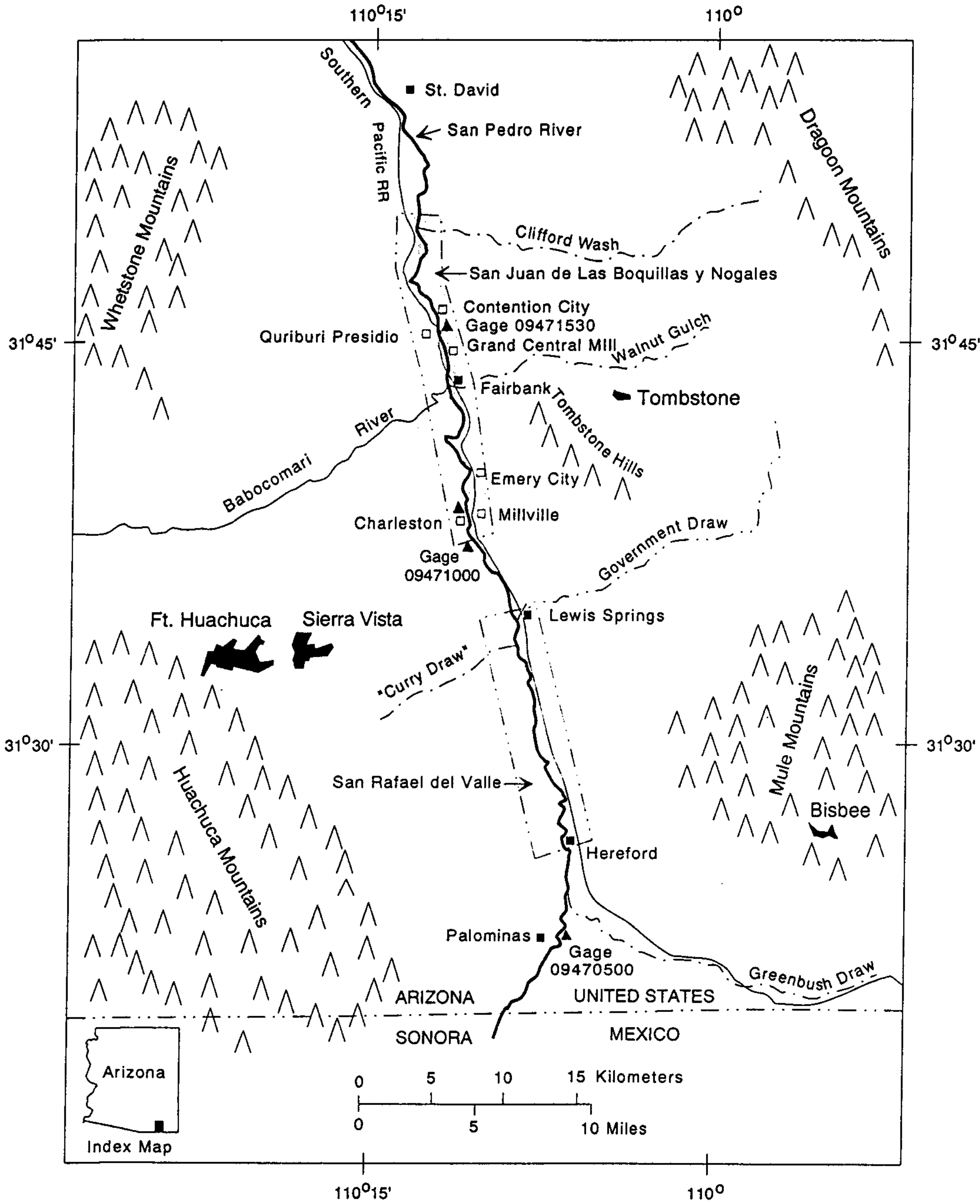
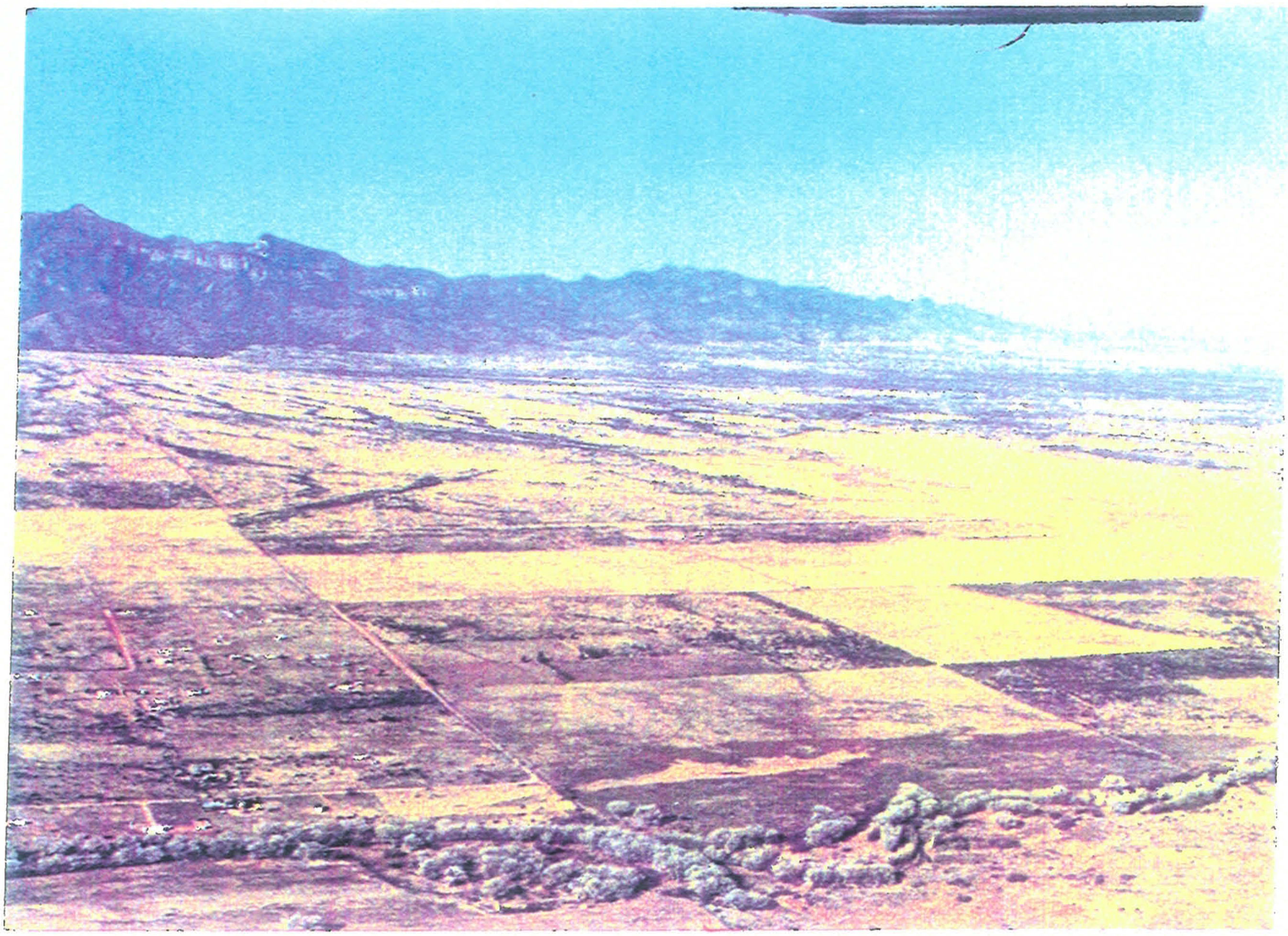


Figure 1. The study area in southeast Arizona. Field studies were undertaken in the river valley between Hereford and just north of Clifford Wash.

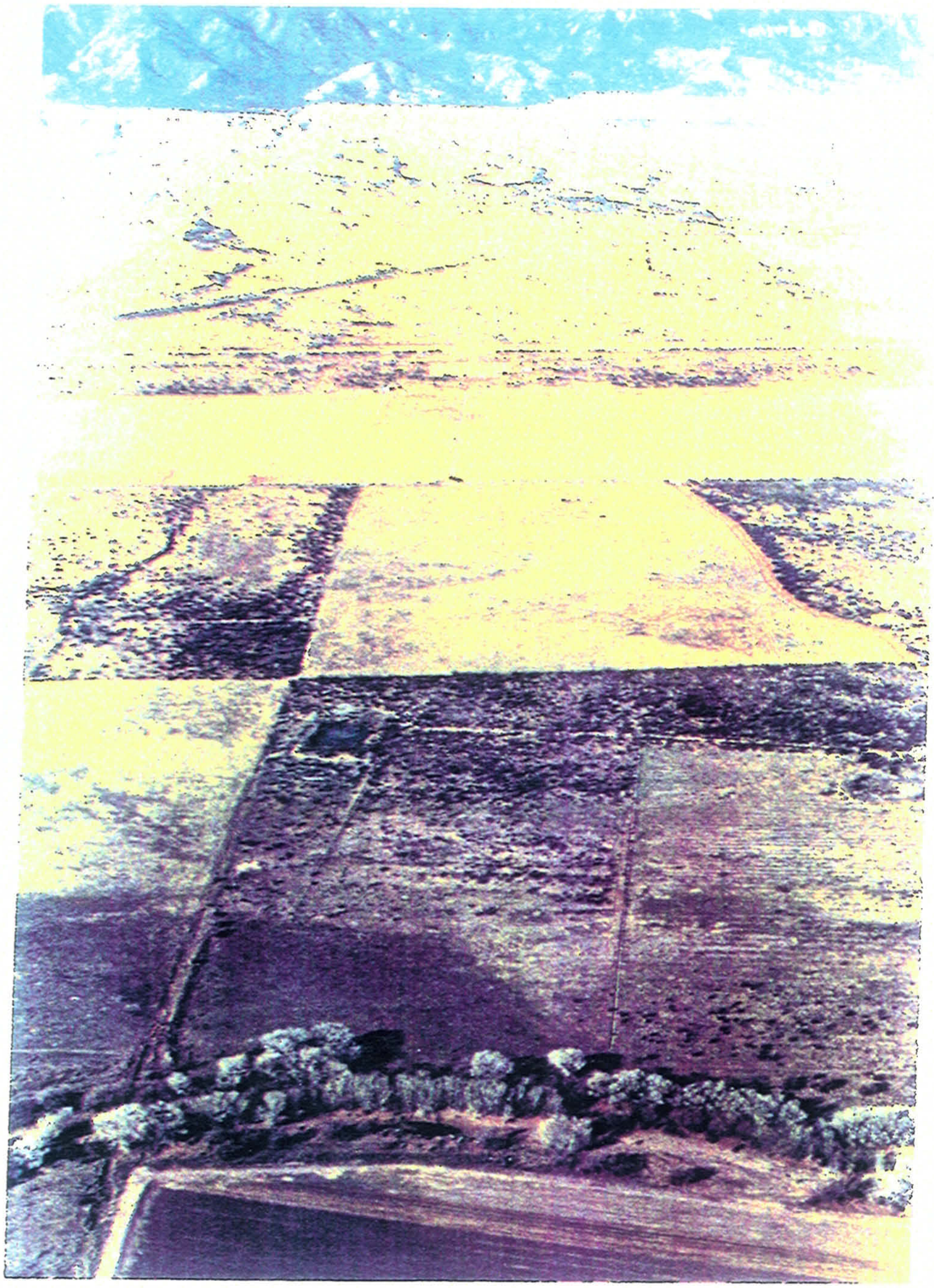


PHOTOGRAPH 4

SAN PEDRO RIVER MAP 1 (NEAR PALOMINAS) ABOUT 2 MILES NORTHEAST FROM PALOMINAS, VIEW TOWARD WEST.

Exhibit 69 in envelope.

Appendix H.



PHOTOGRAPH 6

SAN PEDRO RIVER MAP 1 (NEAR PALOMINAS) ABOUT 2 MILES NORTHEAST FROM PALOMINAS, VIEW TOWARD WEST.

Exhibit 71 in envelope.

Appendix I.

PHOTOGRAPH 7

SAN PEDRO RIVER MAP 1 (NEAR PALOMINAS) ABOUT 1 MILE SOUTH FROM HEREFORD, VIEW TOWARD SOUTHWEST.

Exhibit 72 in envelope.

Appendix J.

PHOTOGRAPH 11

SAN PEDRO RIVER MAP 5 (NEAR CASCABEL) ABOUT 7 MILES SOUTHEAST FROM CASCABEL, VIEW TOWARD EAST.

Exhibit 76 in envelope.

Appendix K.

PHOTOGRAPH 12

SAN PEDRO RIVER MAP 6 (NEAR REDINGTON) ABOUT 8 MILES NORTH FROM REDINGTON, VIEW TOWARD NORTH.

Exhibit 77 in envelope.

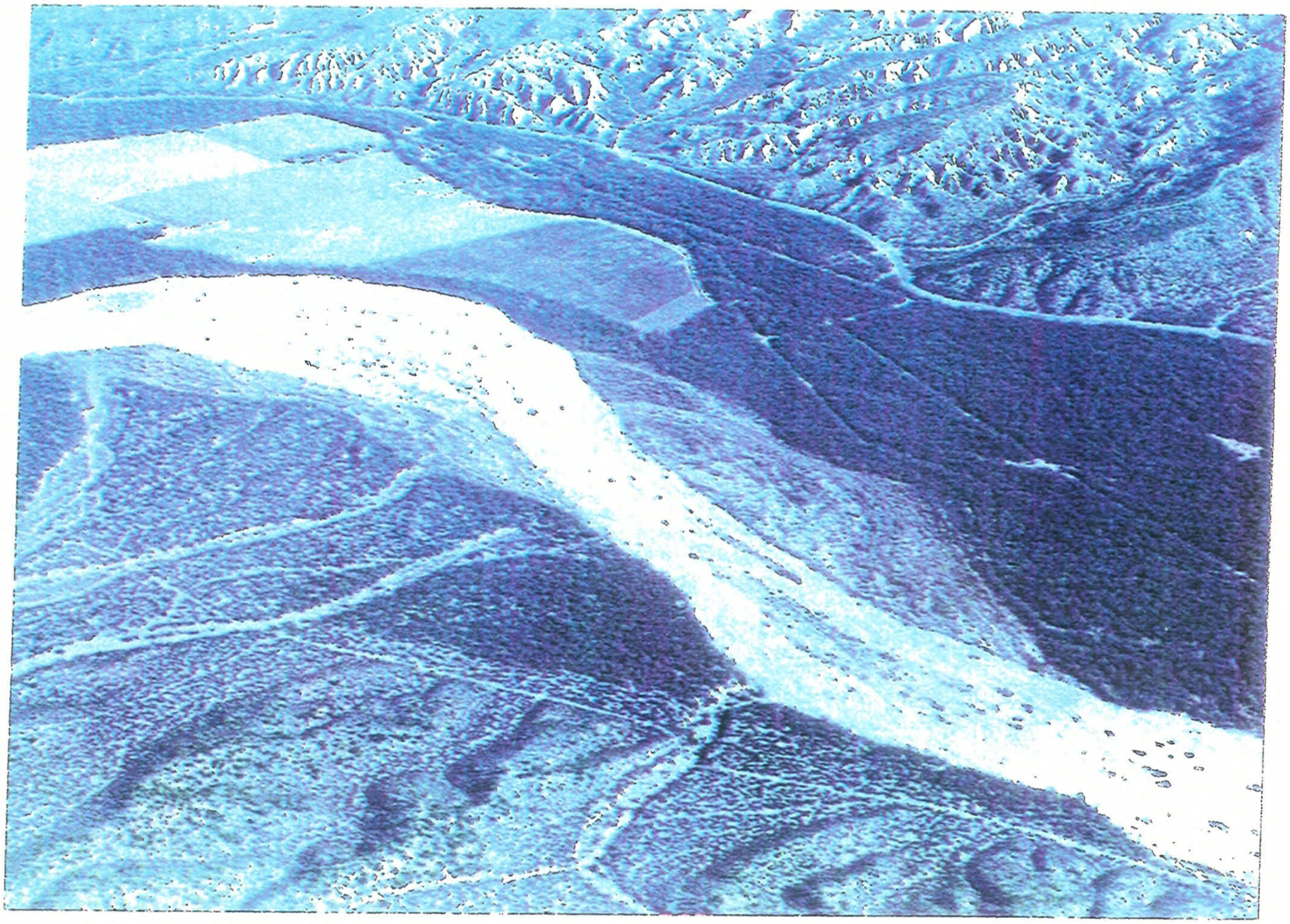
Appendix L.

PHOTOGRAPH 13

SAN PEDRO RIVER MAP 7 (NEAR SAN MANUEL) ABOUT 3 MILES NORTHEAST FROM SAN MANUEL, VIEW TOWARD NORTHWEST.

Exhibit 78 in envelope.

Appendix M.

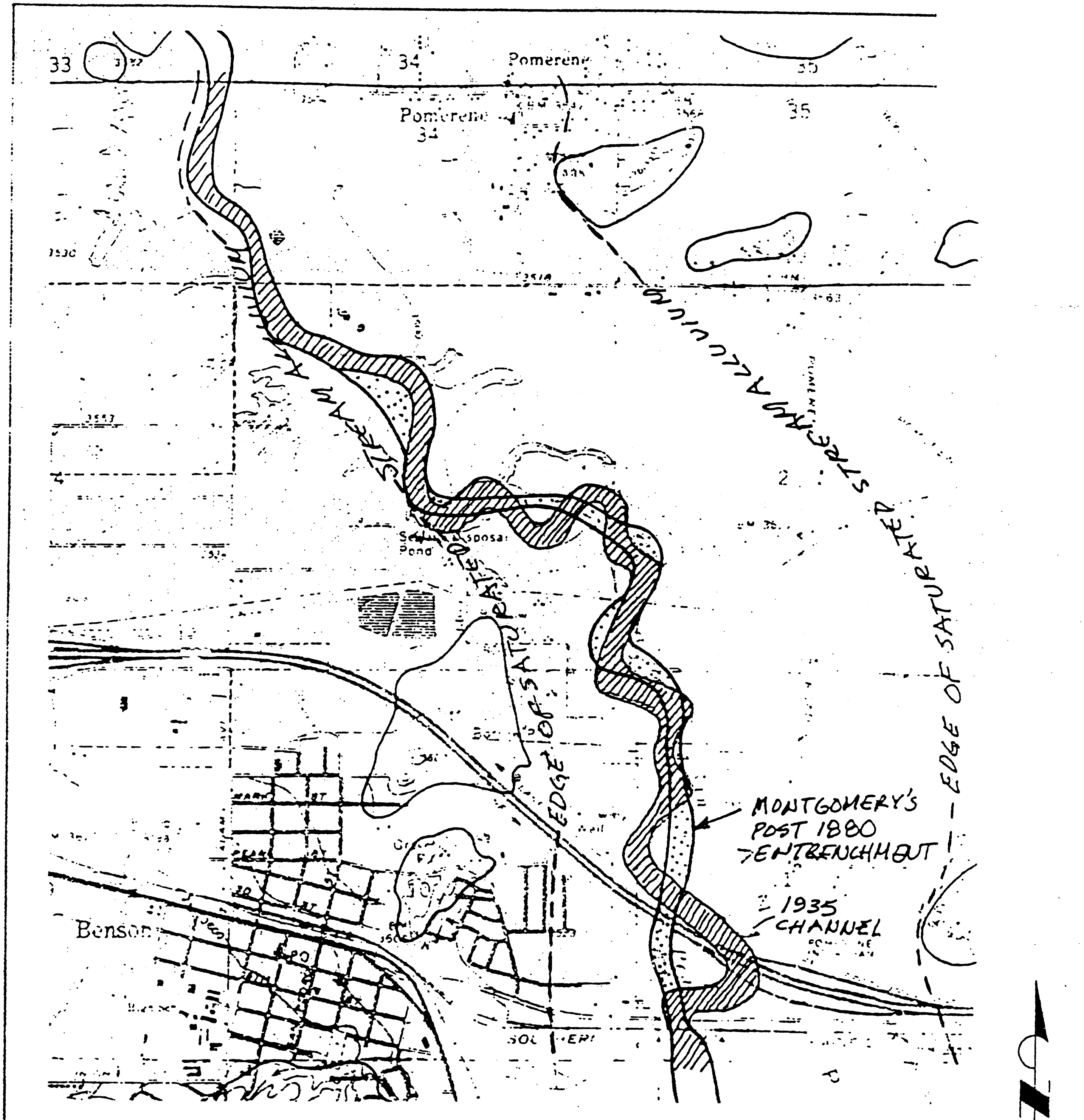


PHOTOGRAPH 14

SAN PEDRO RIVER MAP 7 (NEAR SAN MANUEL) ABOUT 1 MILE SOUTH FROM MAMMOTH, VIEW TOWARD NORTHEAST.

Exhibit 79 in envelope.

Appendix N.



Scale 1" = 2000'

NOTE: Shift in CHANNEL location of as much as 1100 feet since 1935. Further notice Montgomery's mapping using recent air photos does not agree well with earlier channel location. Since the entrenchment has supposedly enlarged around the original entrenchment location the 1935 channel should wholly be located within the current limits of the Post 1880 Entrenchment.

COMPARISON OF 1935 SAN PEDRO RIVER CHANNEL AND MONTGOMERY'S POST 1880 ENTRENCHMENT - NEAR BENSON

EXPLANATION

Edge of Saturated Stream Alluvium from SRP Map(Trial Exhibit)

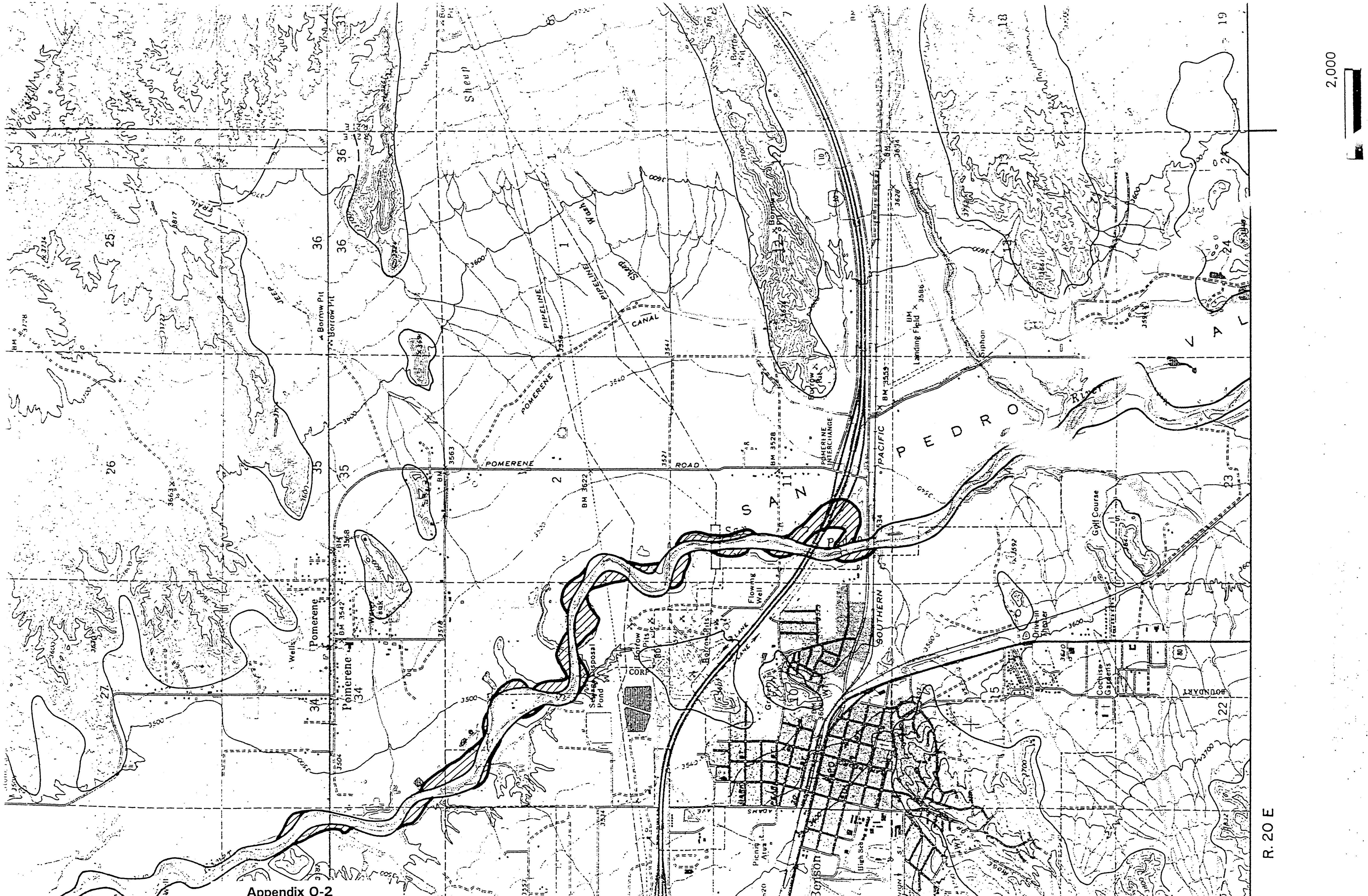
Location of 1935 River Channel from Air Photo

Location of Post 1880 Entrenchment from Montgomery's Map(Trial Exhibit)

LEONARD RICE CONSULTING WATER ENGINEERS, INC.
2401 Fifteenth Street, Suite 300
Denver, Colorado 80202-1143 U.S.A.
(303) 455-9589 • Fax (303) 455-0115

DWN: JRF	DATE: 5/6/94	PROJECT: 968GLE01	FIGURE: 2

Appendix O-1
Exhibit 317

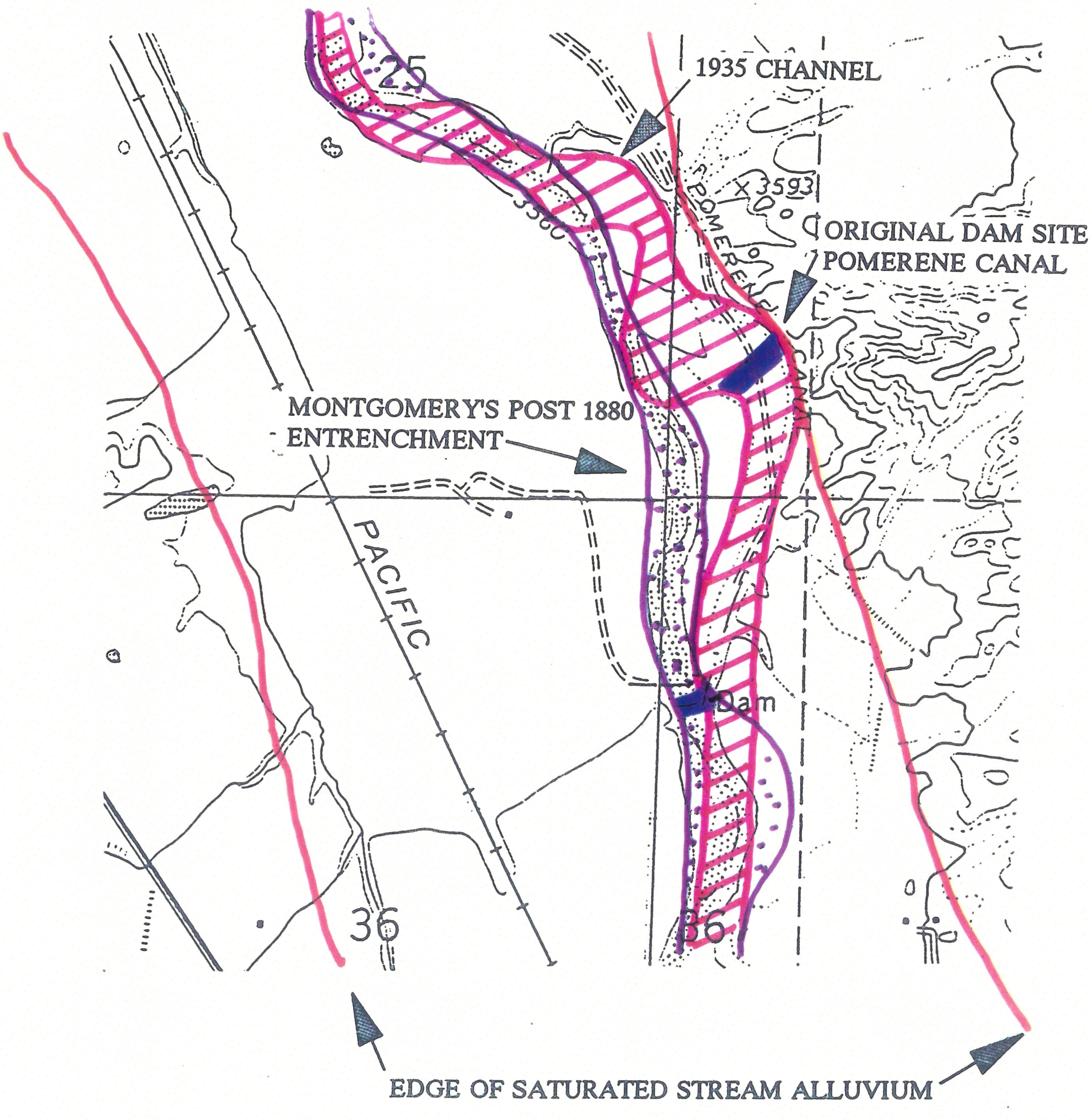


Appendix O-2
Exhibit 338

EXTENT OF ENTRENCHMENT OF SAN PEDRO RIVER

VICINITY OF POMERENE CANAL COMPANY DAM

T.17S., R.20-21E.

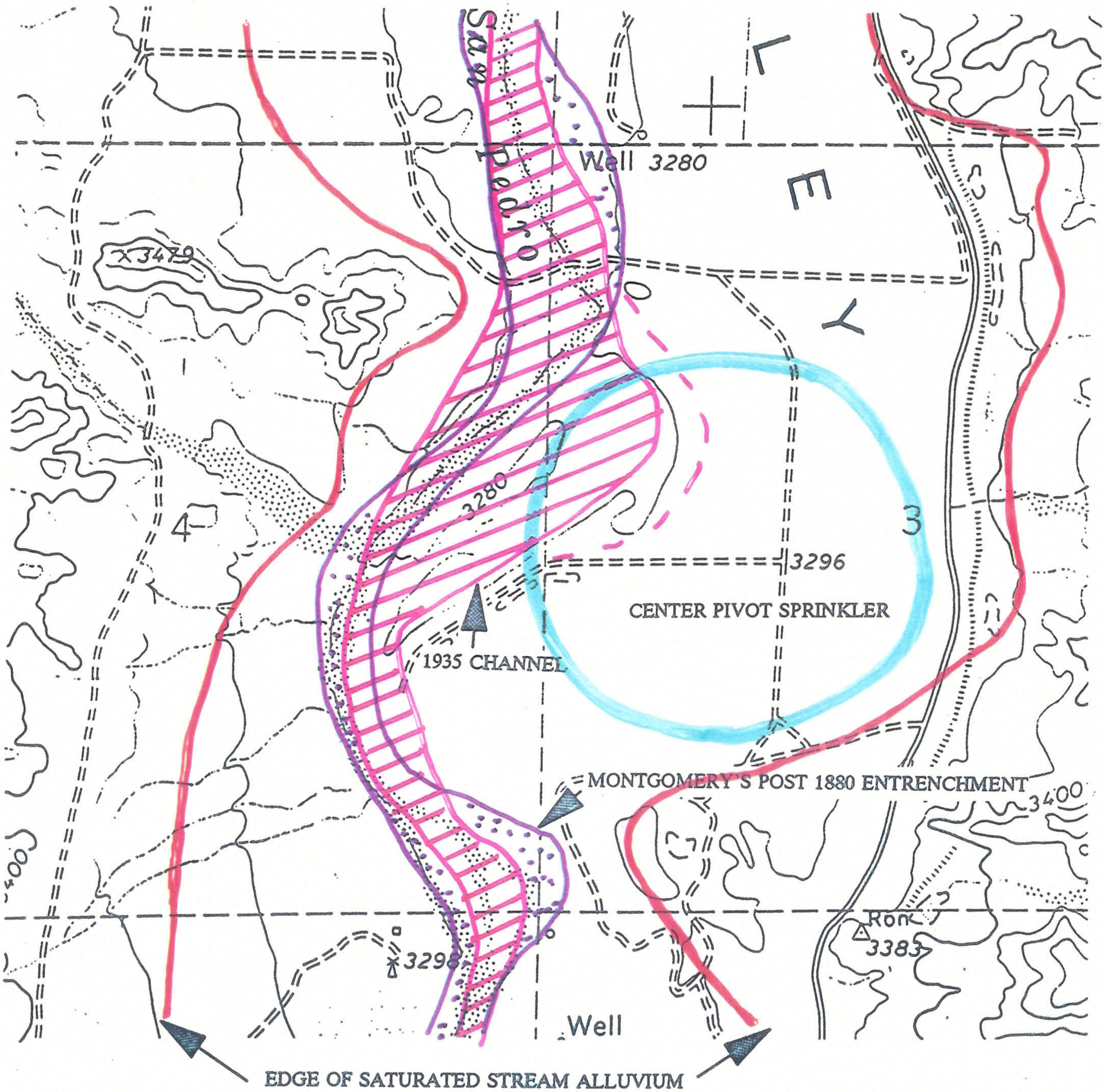


Appendix O-3
Exhibit 319

EXTENT OF ENTRENCHMENT OF SAN PEDRO RIVER

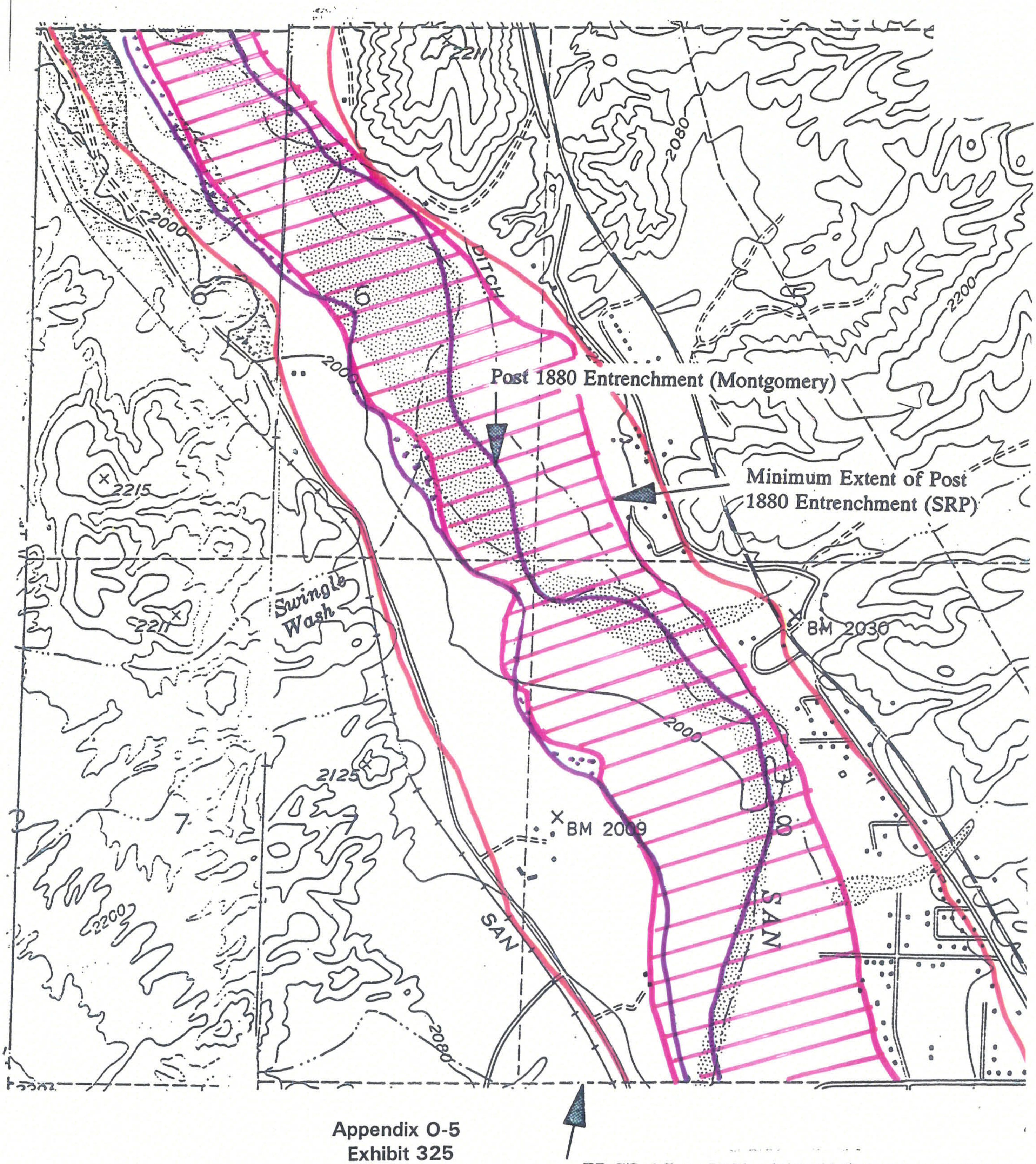
VICINITY OF AWDR EXHIBIT 260

T.14-15 S., R.20E.



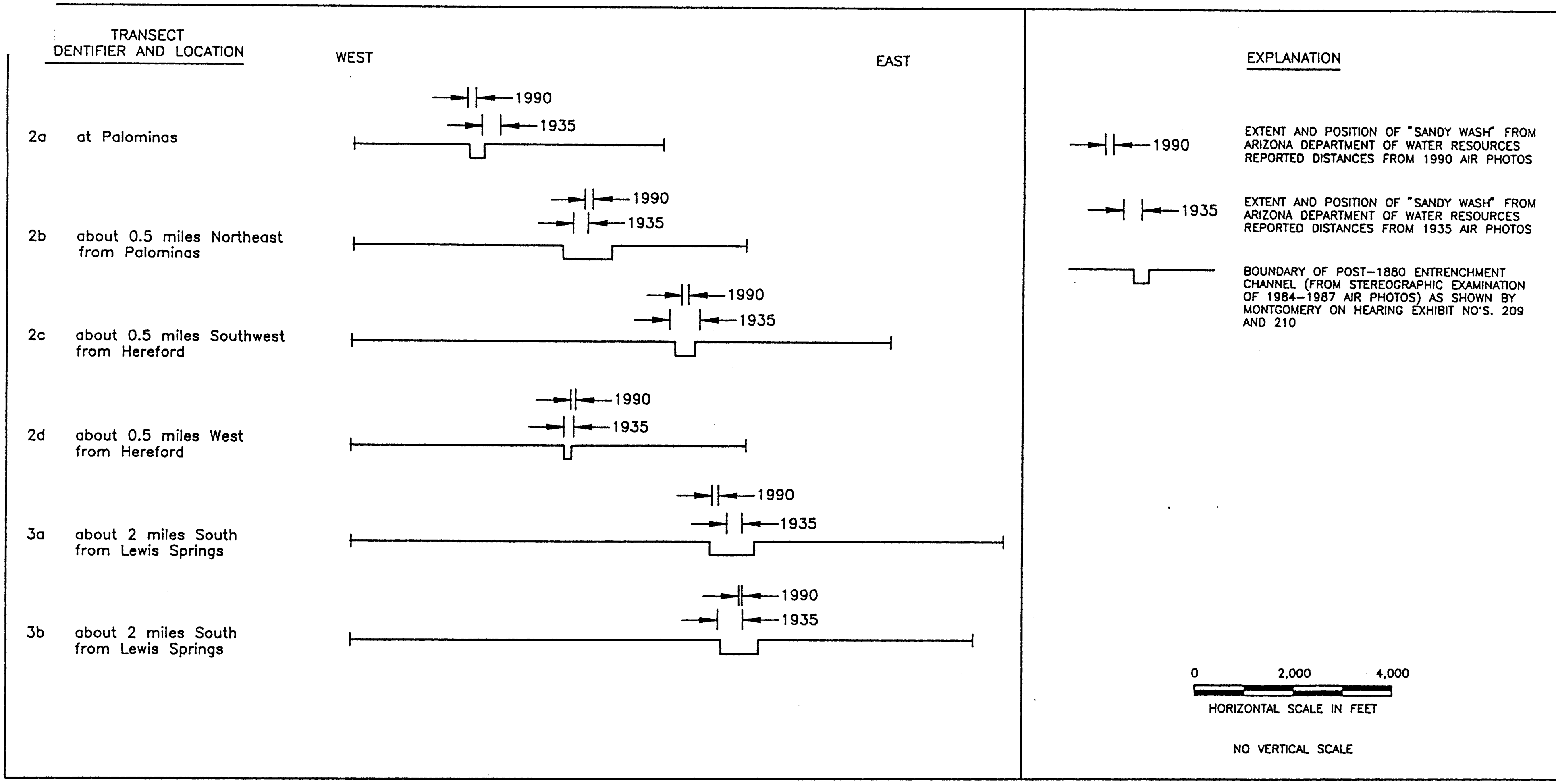
Appendix O-4
Exhibit 320

EXTENT OF ENTRENCHMENT OF SAN PEDRO RIVER
VICINITY OF PAUL SALE PROPERTY
T.6S., R.16E.



Appendix O-5
Exhibit 325

EDGE OF SATURATED STREAM ALLUVIUM

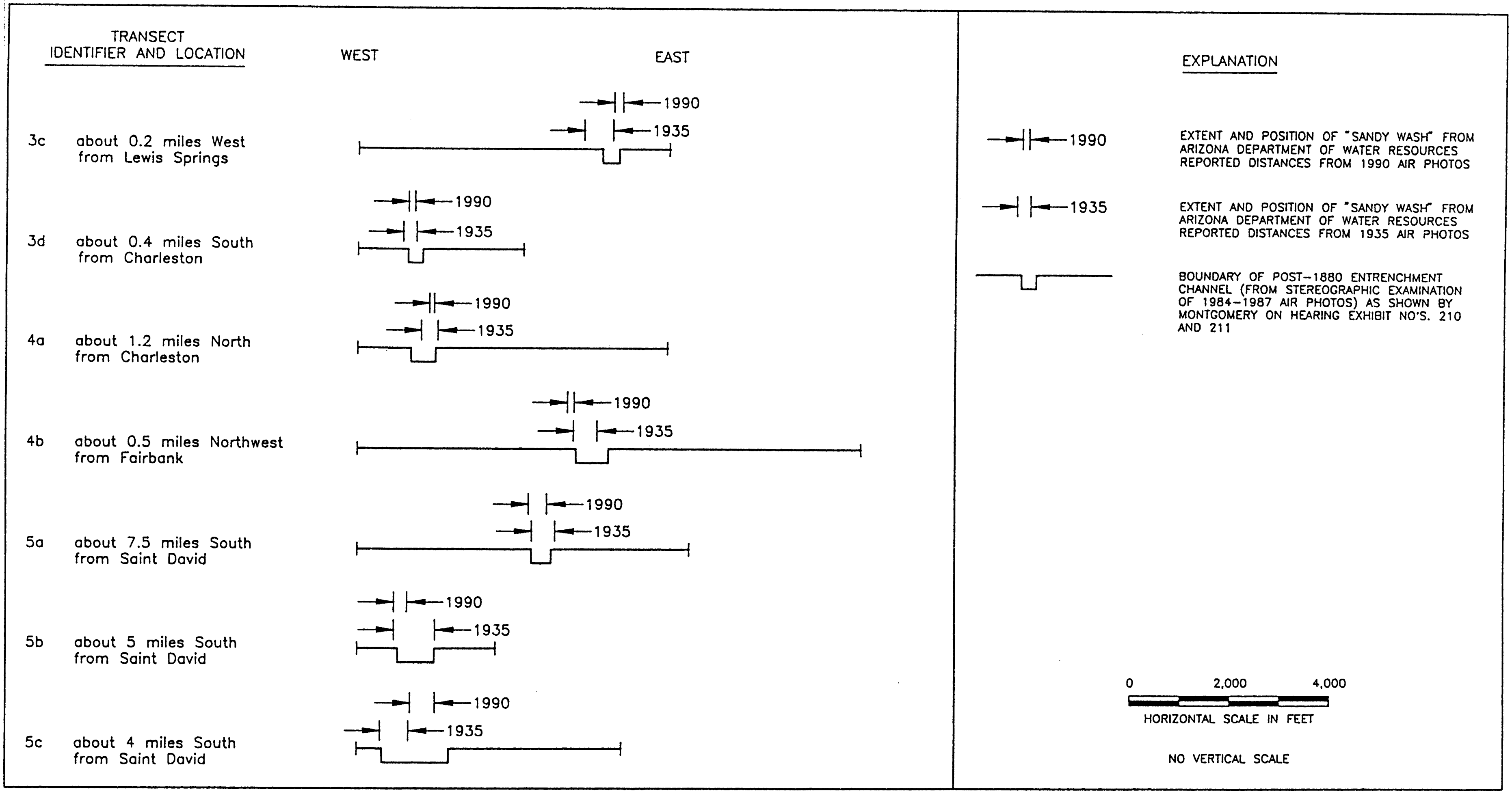


PHYSICAL RELATION BETWEEN "SANDY WASH" LOCATIONS IN 1935 AND 1990 BASED ON ARIZONA DEPARTMENT OF WATER RESOURCES REPORTED DISTANCES IN FEET, AND LATERAL EXTENT OF POST-1880 ENTRENCHMENT CHANNEL BASED ON HEARING EXHIBIT NUMBERS 209 AND 210 FOR TRANSECTS 2a, 2b, 2c, 2d, 3a, AND 3b.

954F-GUC\FIGS\06-02-94

ERROL L. MONTGOMERY & ASSOCIATES, INC.
CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA

Appendix O-6
Exhibit 332

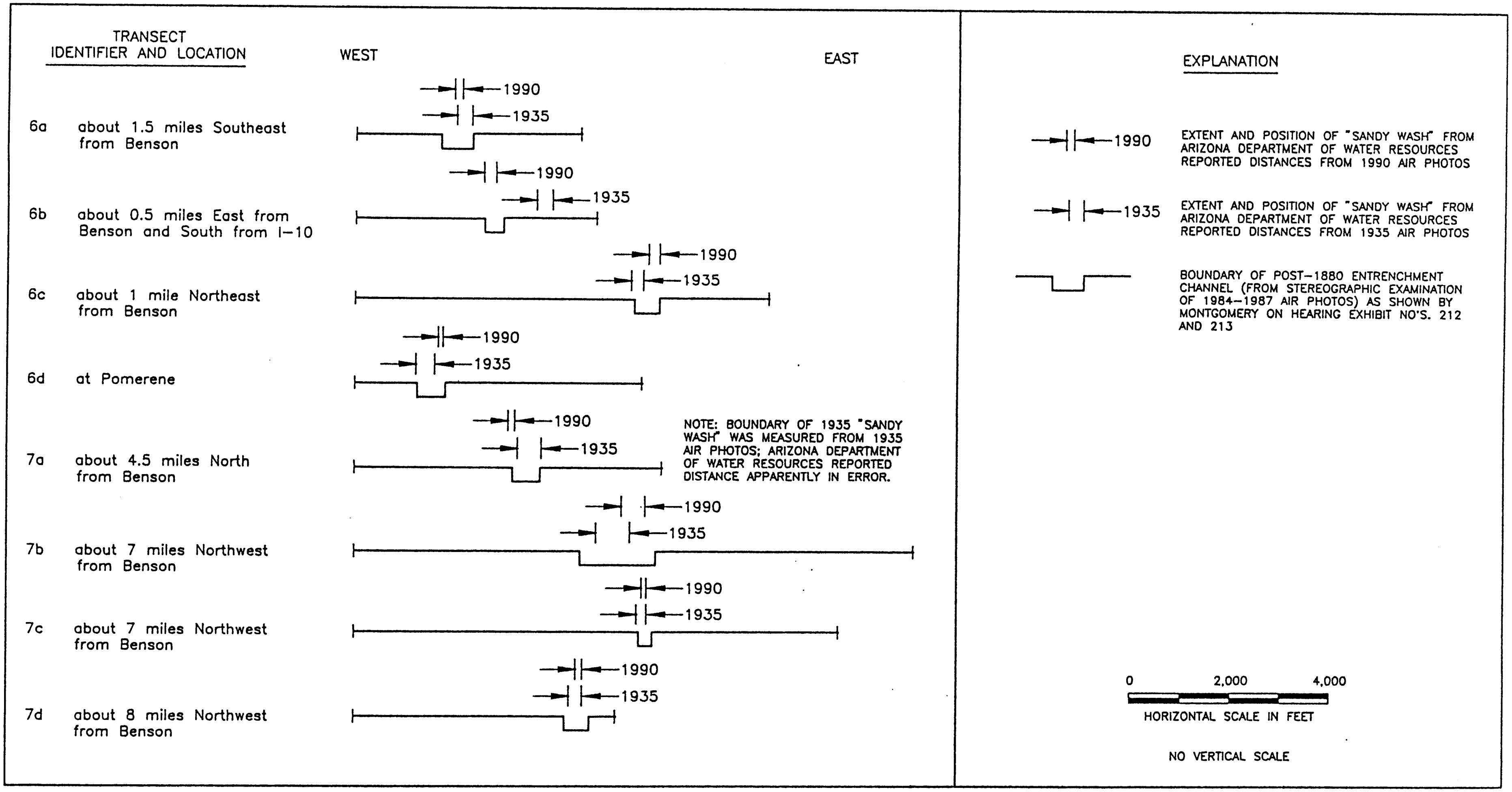


PHYSICAL RELATION BETWEEN "SANDY WASH" LOCATIONS IN 1935 AND 1990 BASED ON ARIZONA DEPARTMENT OF WATER RESOURCES REPORTED DISTANCES IN FEET, AND LATERAL EXTENT OF POST-1880 ENTRENCHMENT CHANNEL BASED ON HEARING EXHIBIT NUMBERS 210 AND 211 FOR TRANSECTS 3c, 3d, 4a, 4b, 5a, 5b, AND 5c

954F-GUC\FIG6\06-06-94

ERROL L. MONTGOMERY & ASSOCIATES, INC.
CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA

Appendix O-7
Exhibit 333

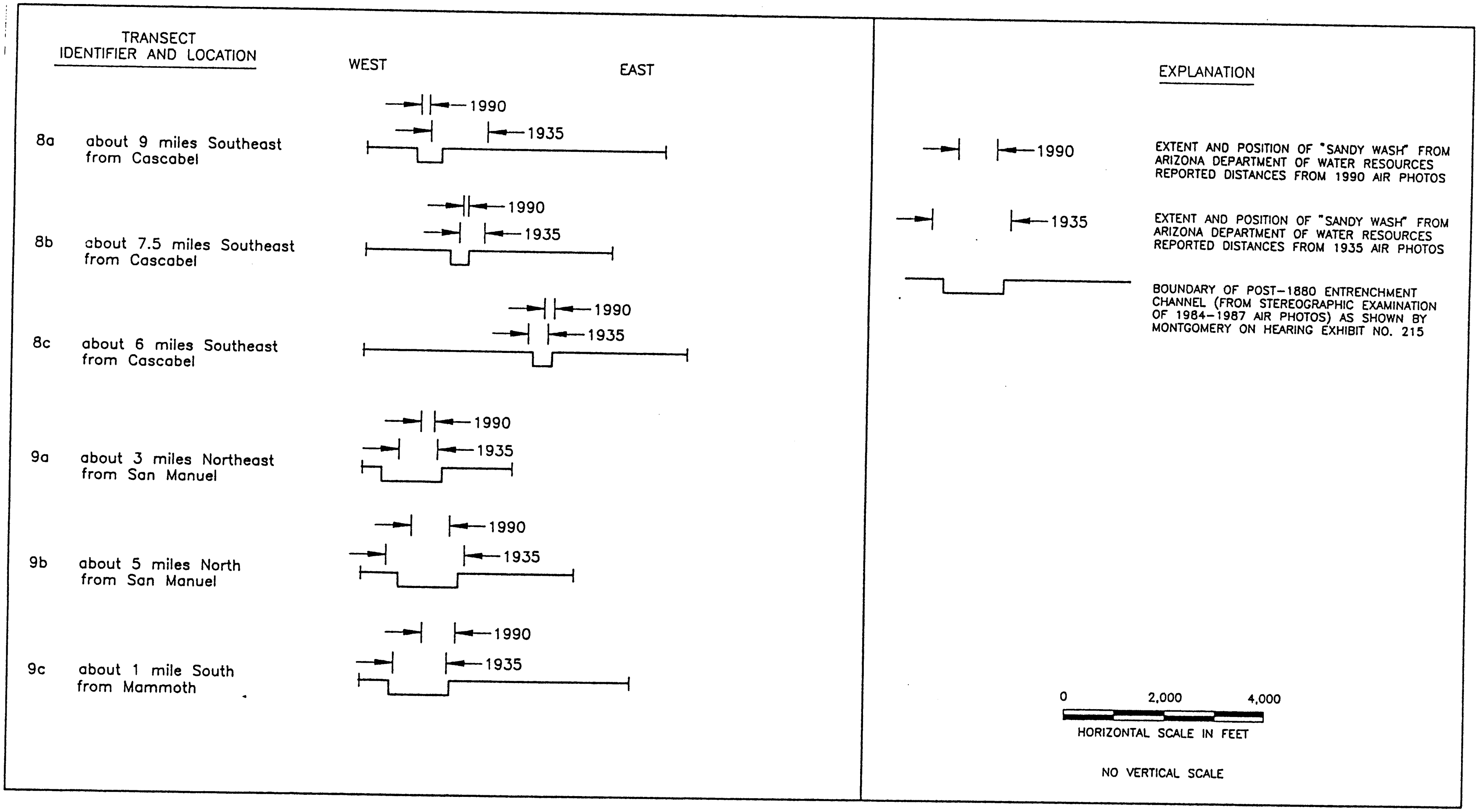


PHYSICAL RELATION BETWEEN "SANDY WASH" LOCATIONS IN 1935 AND 1990 BASED ON ARIZONA DEPARTMENT OF WATER RESOURCES REPORTED DISTANCES IN FEET, AND LATERAL EXTENT OF POST-1880 ENTRENCHMENT CHANNEL BASED ON HEARING EXHIBIT NUMBERS 212 AND 213 FOR TRANSECTS 6a, 6b, 6c, 6d, 7a, 7b, 7c, AND 7d,

954F-GUC\FIG7\06-06-94

ERROL L. MONTGOMERY & ASSOCIATES, INC.
CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA

Appendix O-8
Exhibit 334



PHYSICAL RELATION BETWEEN "SANDY WASH" LOCATIONS IN 1935 AND 1990 BASED ON ARIZONA DEPARTMENT OF WATER RESOURCES REPORTED DISTANCES IN FEET, AND LATERAL EXTENT OF POST-1880 ENTRENCHMENT CHANNEL BASED ON HEARING EXHIBIT NUMBER 215 FOR TRANSECTS 8a, 8b, 8c, 9a, 9b, AND 9c

954F-GUC\FIG8\06-03-94

ERROL L. MONTGOMERY & ASSOCIATES, INC.
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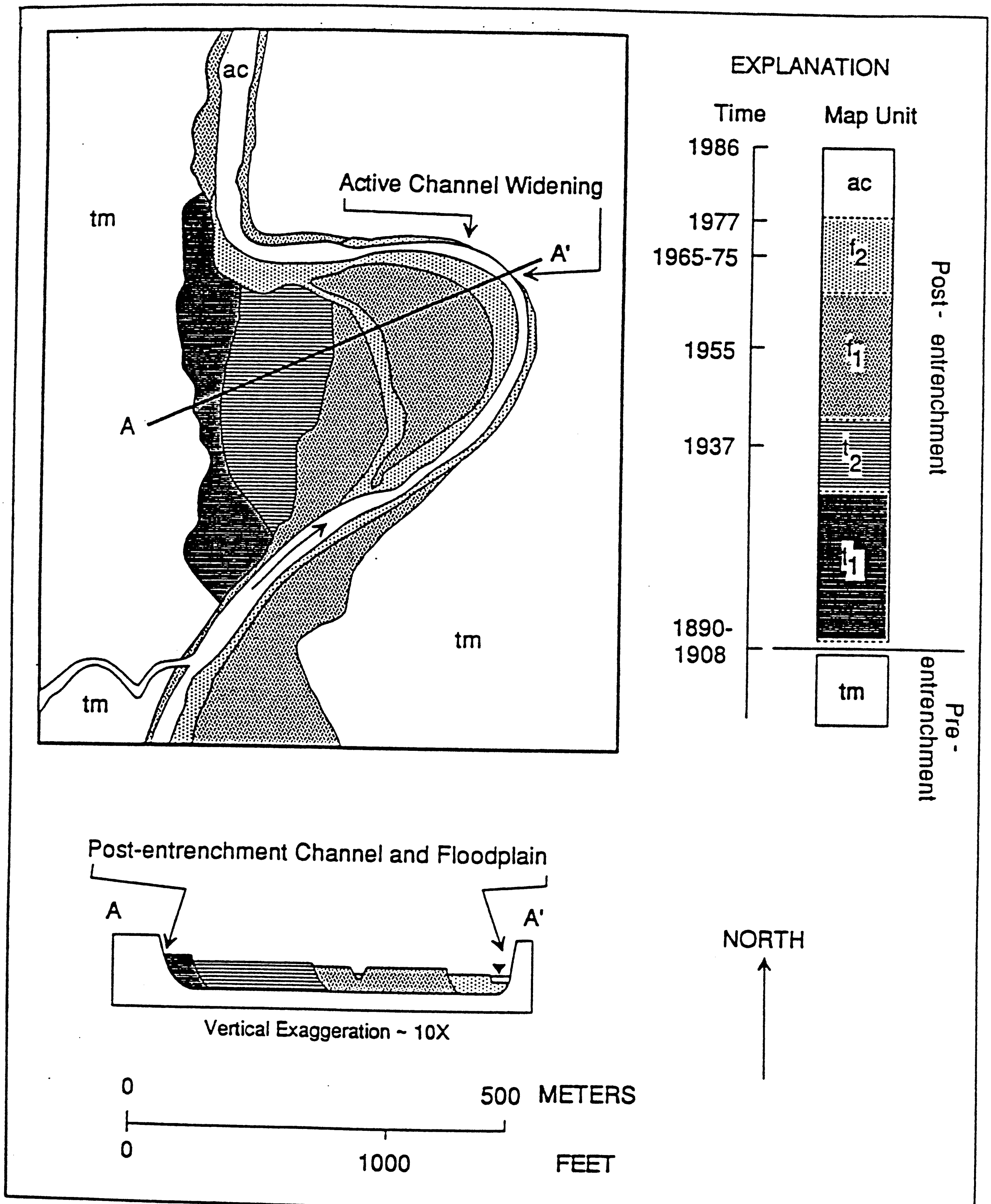
TUCSON, ARIZONA

Appendix O-9
Exhibit 335

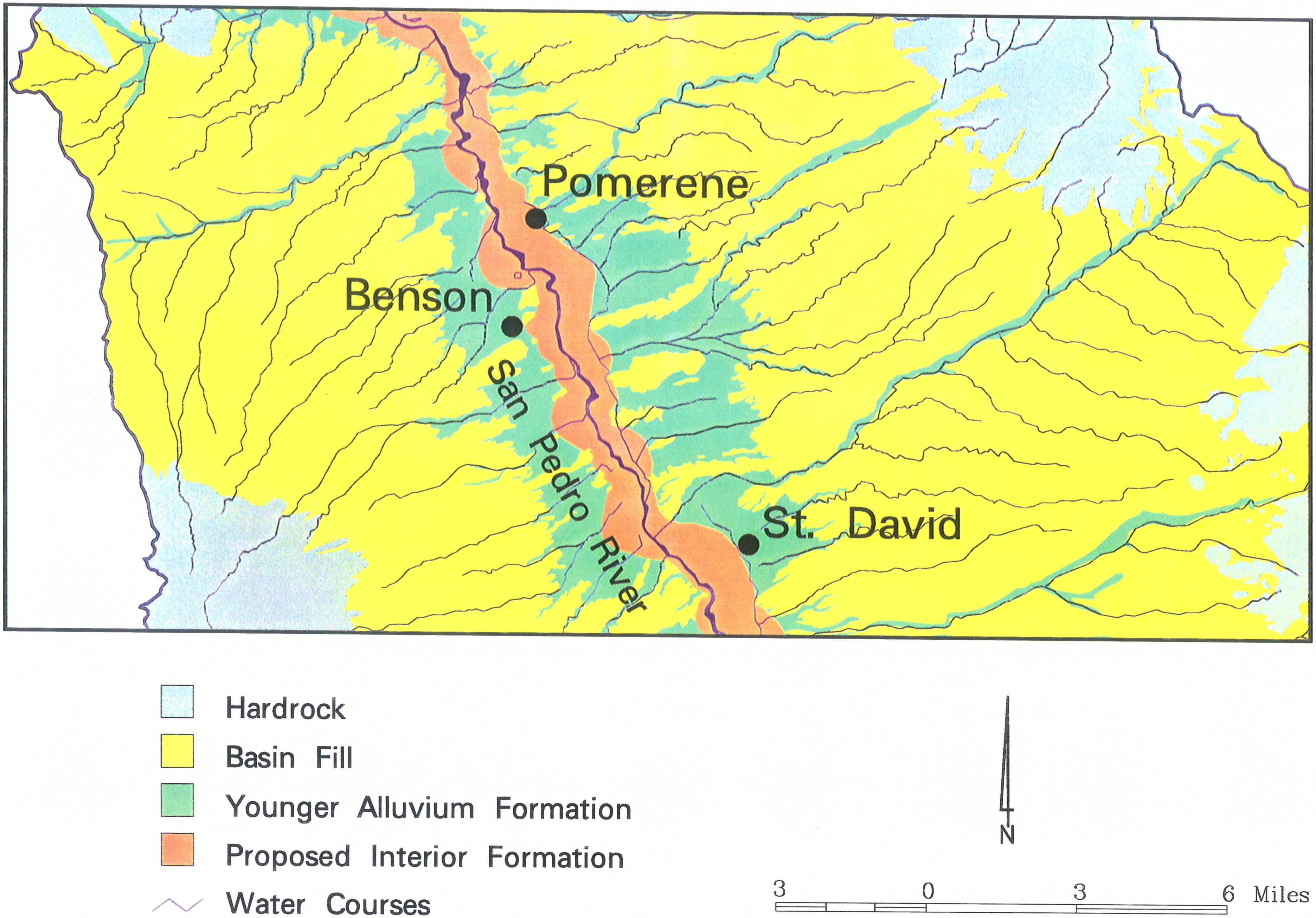


(Modified from Hereford, 1993)

LATERAL CHANNEL MIGRATION IN THE SAN PEDRO RIVER

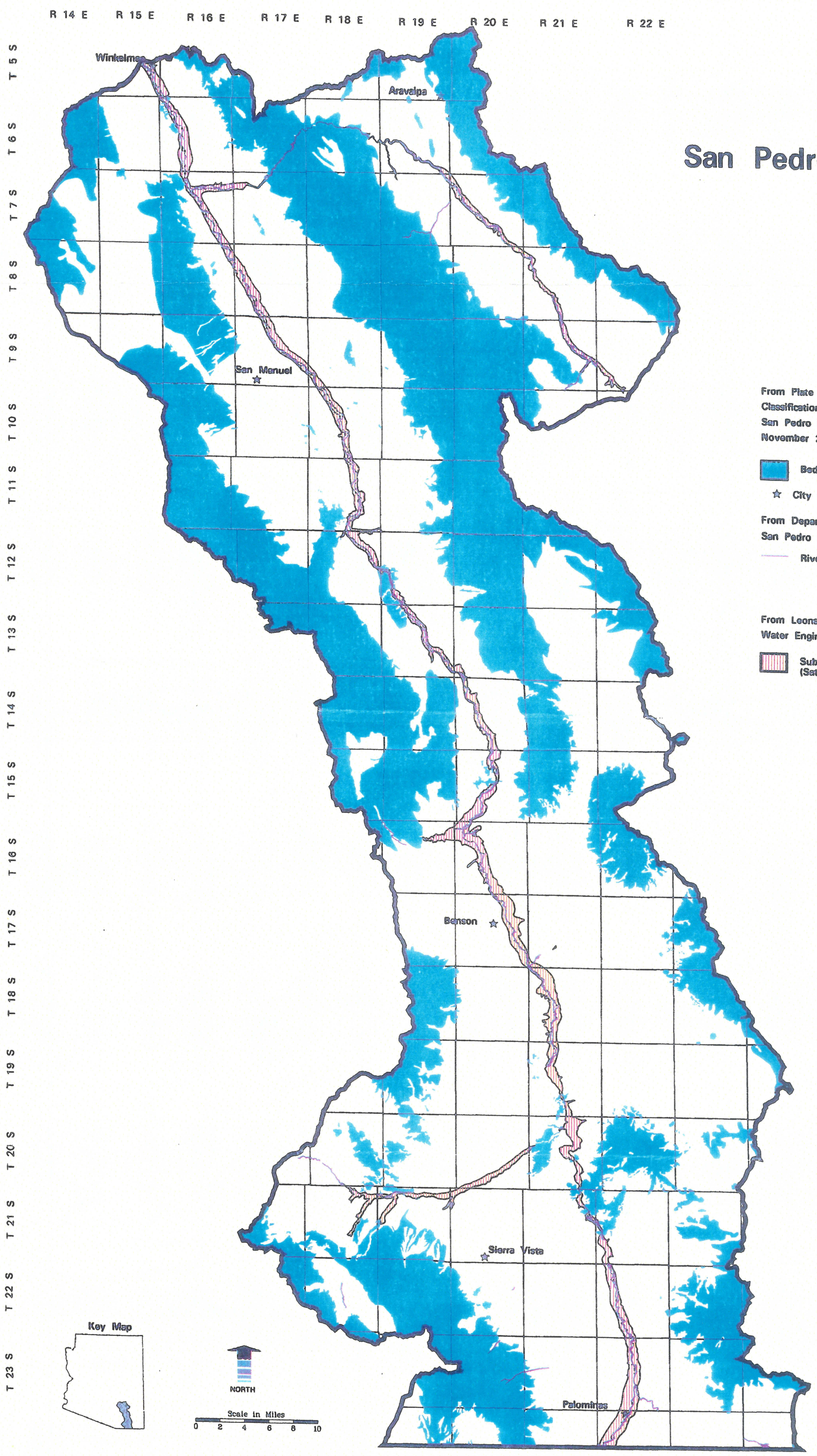
Appendix P
Exhibit 2

Hydrogeology of the Benson Area



Appendix Q Exhibit 266

San Pedro Watershed



From Plate 1 (Delineation of Well Classification Zones), Volume 1A
San Pedro Hydrographic Survey Report,
November 20, 1991

Bedrock Area

City or Town

From Department of Water Recources Final
San Pedro Hydrographic Survey Report

Rivers

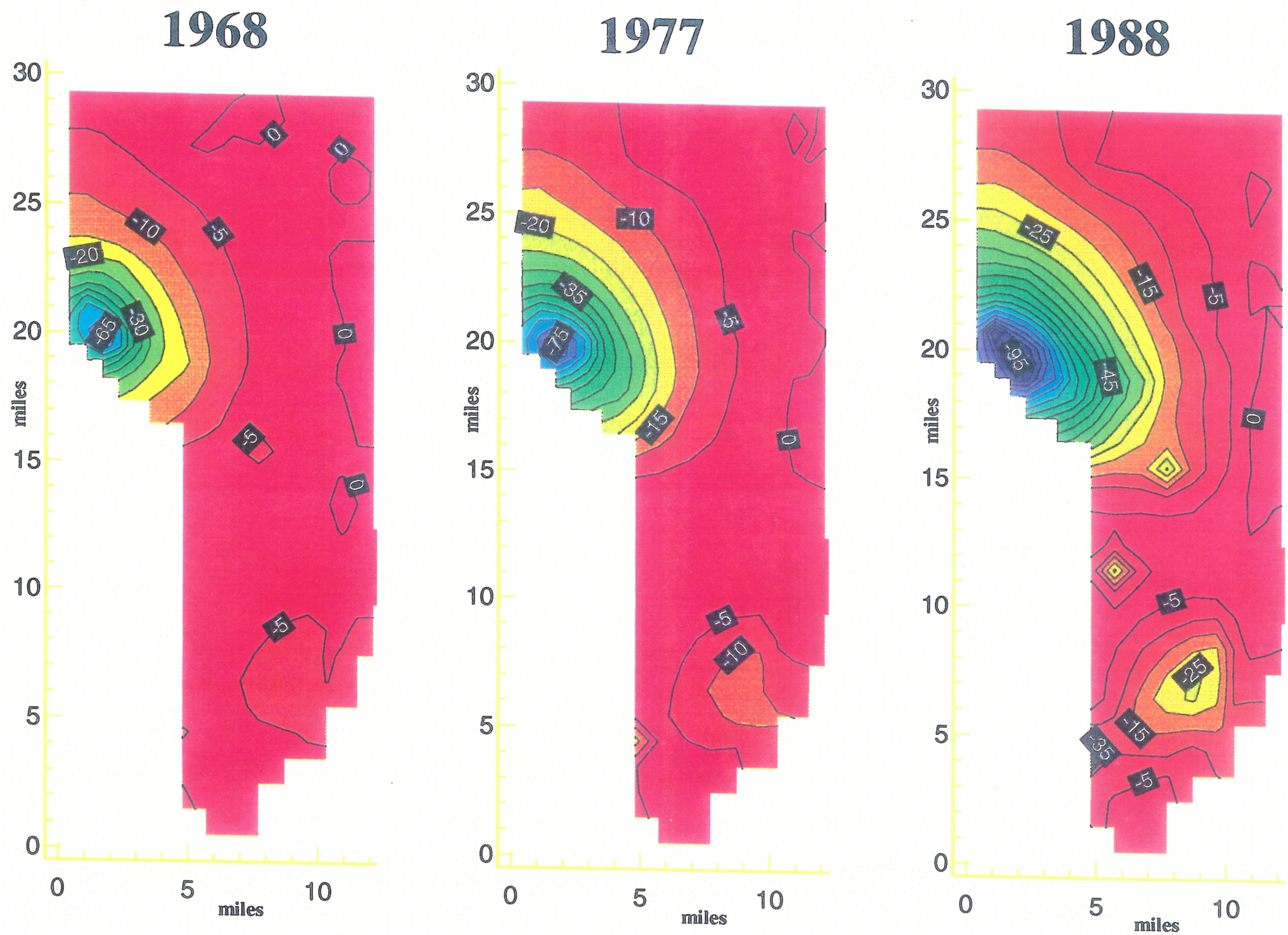
From Leonard Rice Consulting
Water Engineers for SRP

Subflow Zone
(Saturated Stream Alluvium)

Figure 8.1

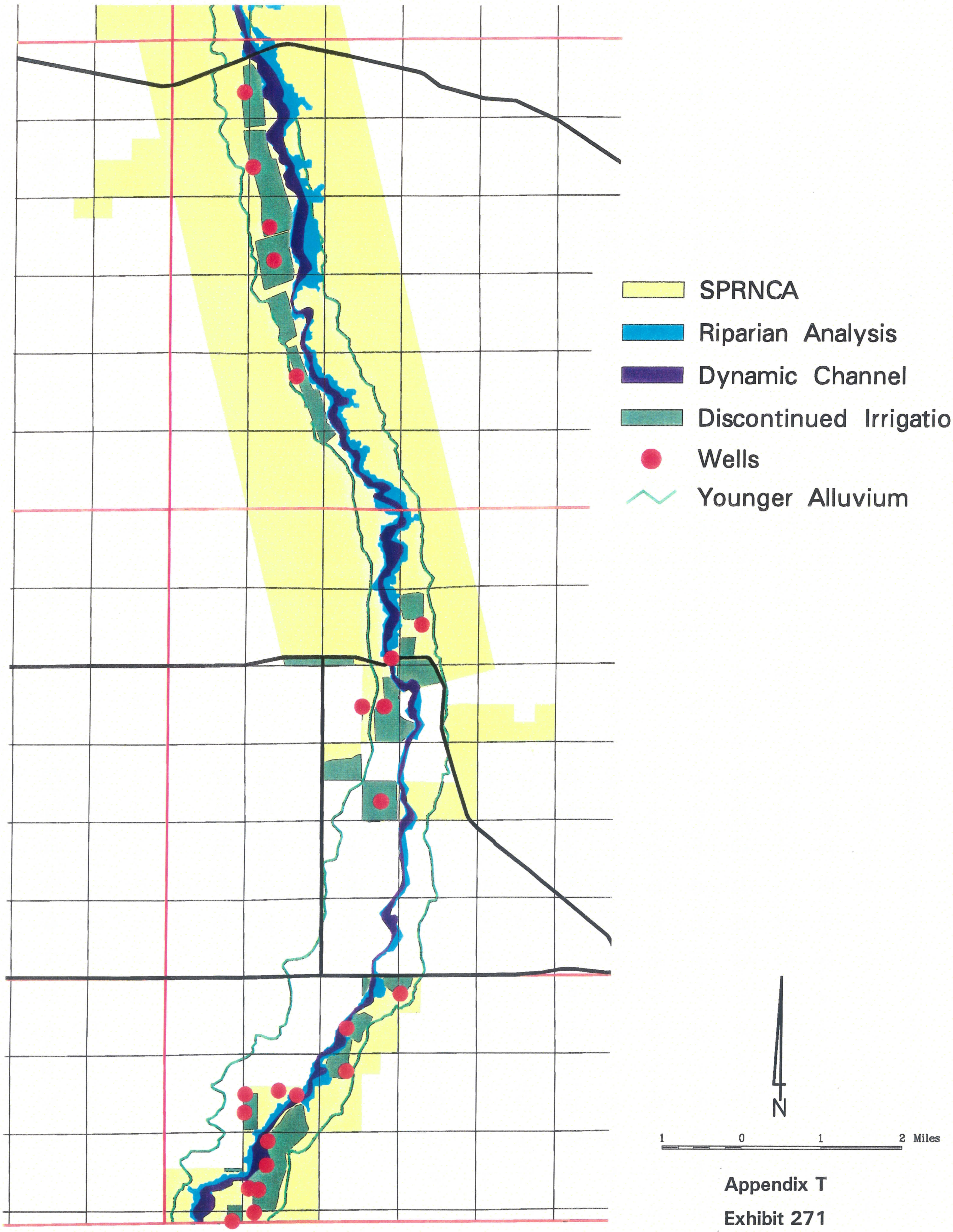
/home/carto/sanped/fig12.aml December 6, 1993

Drawdown since substantial pumping started in 1940
(model predicted)



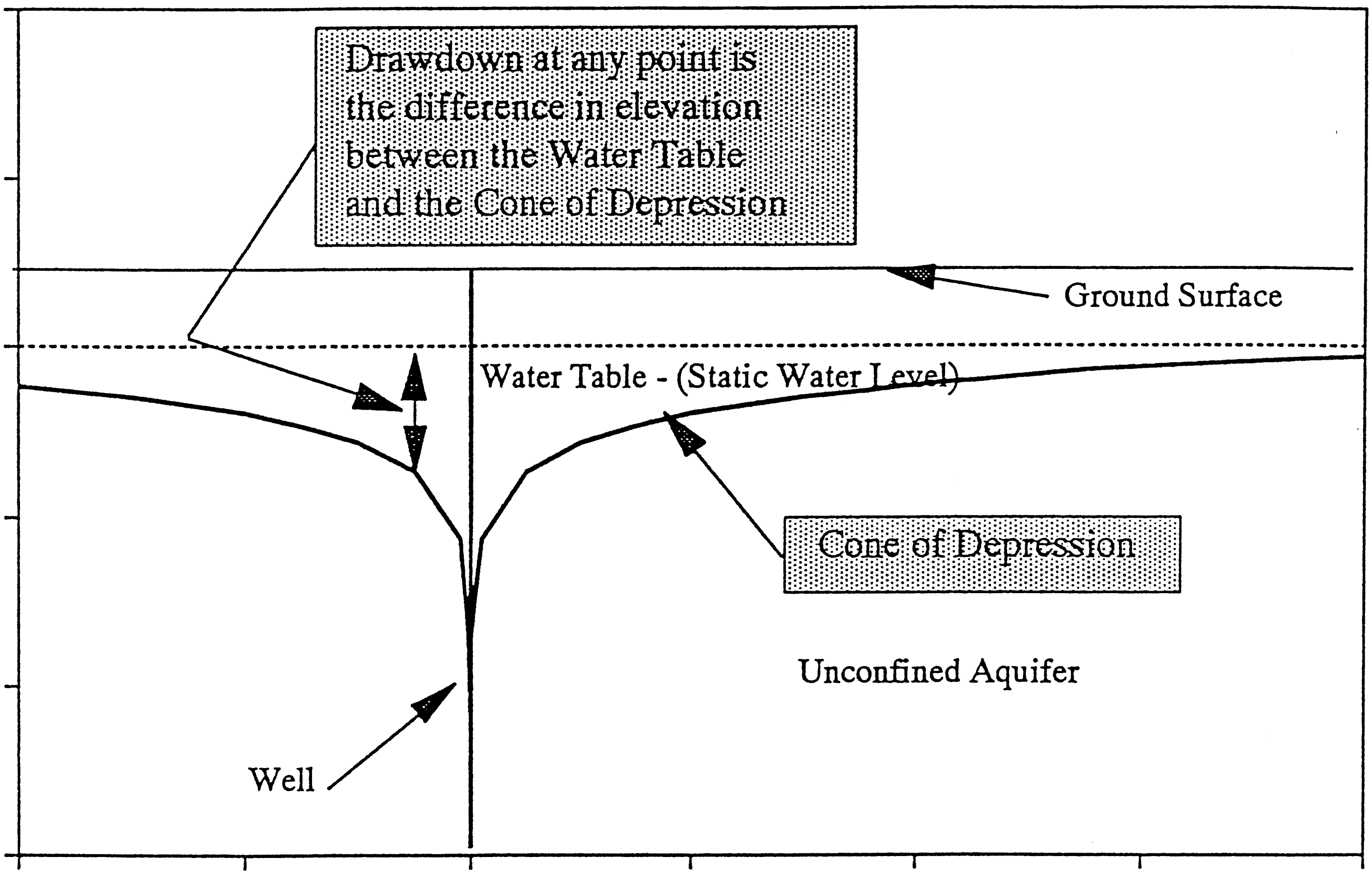
Appendix S
Exhibit 163

Discontinued Irrigation within SPRNCA



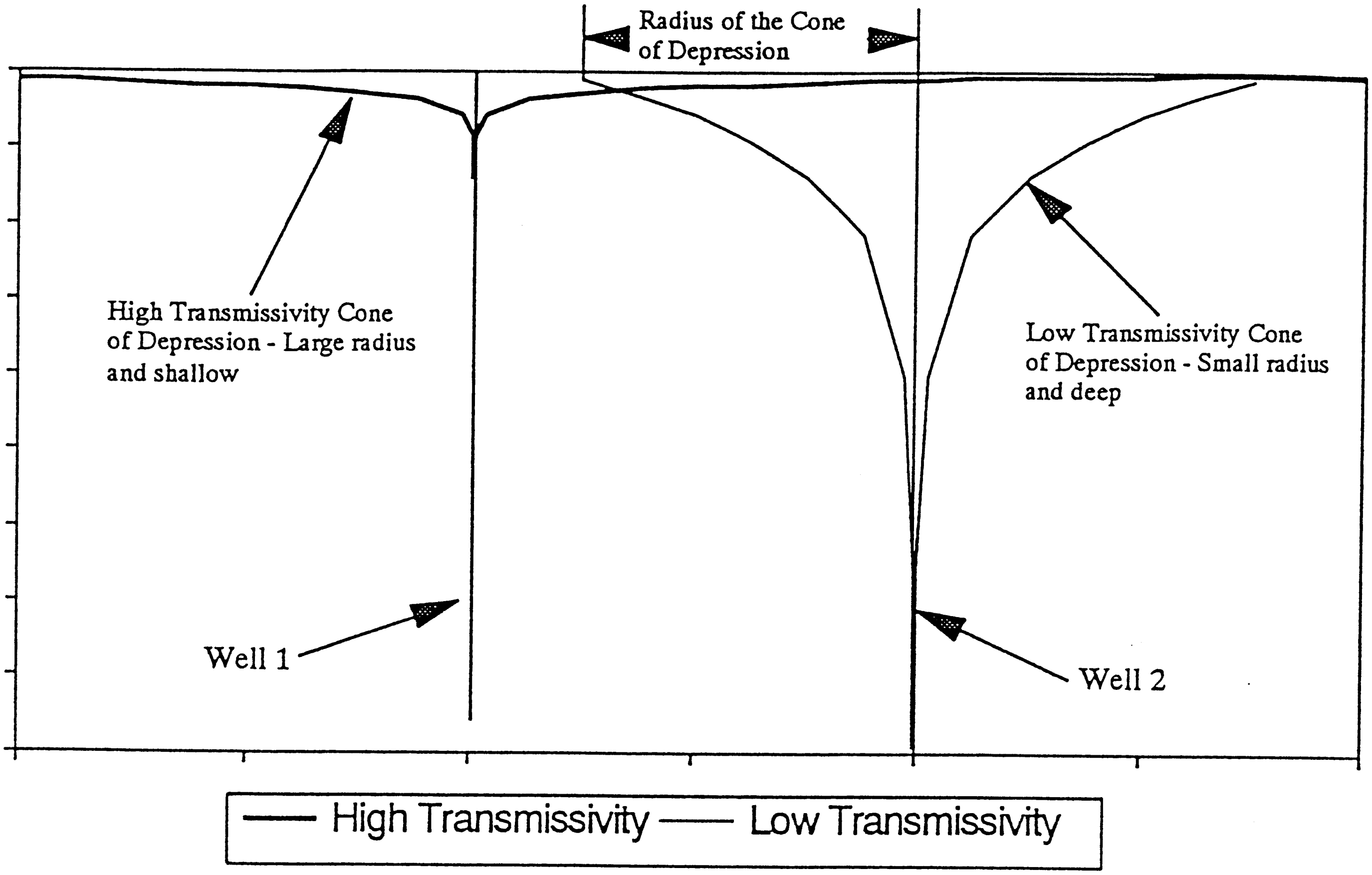
Appendix T

Exhibit 271



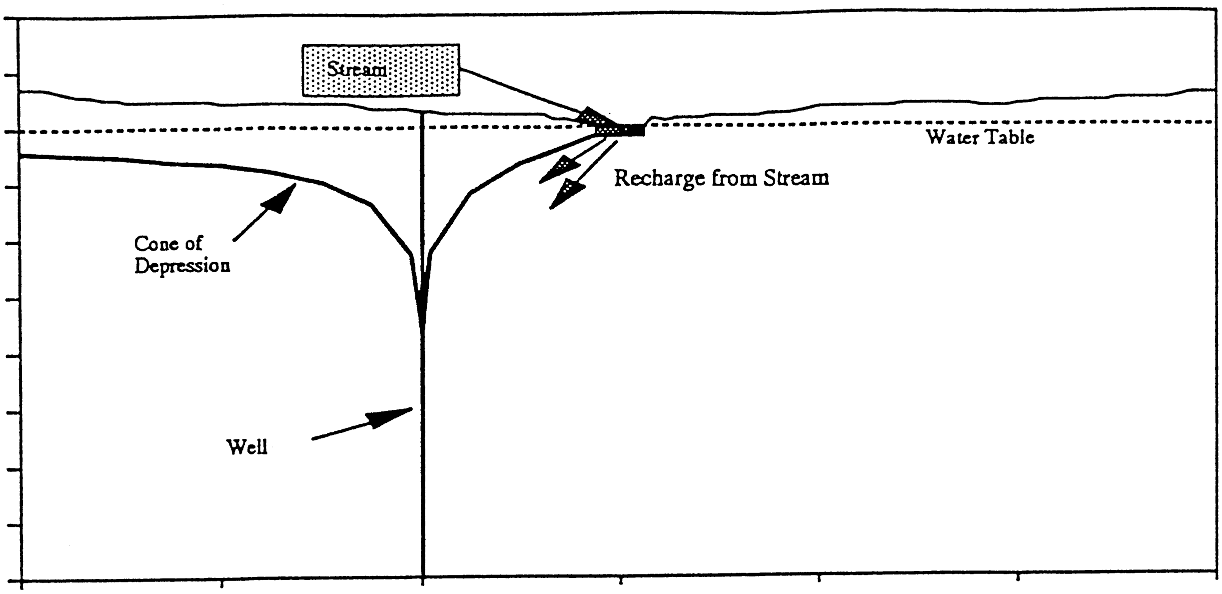
CONE OF DEPRESSION AND DRAWDOWN

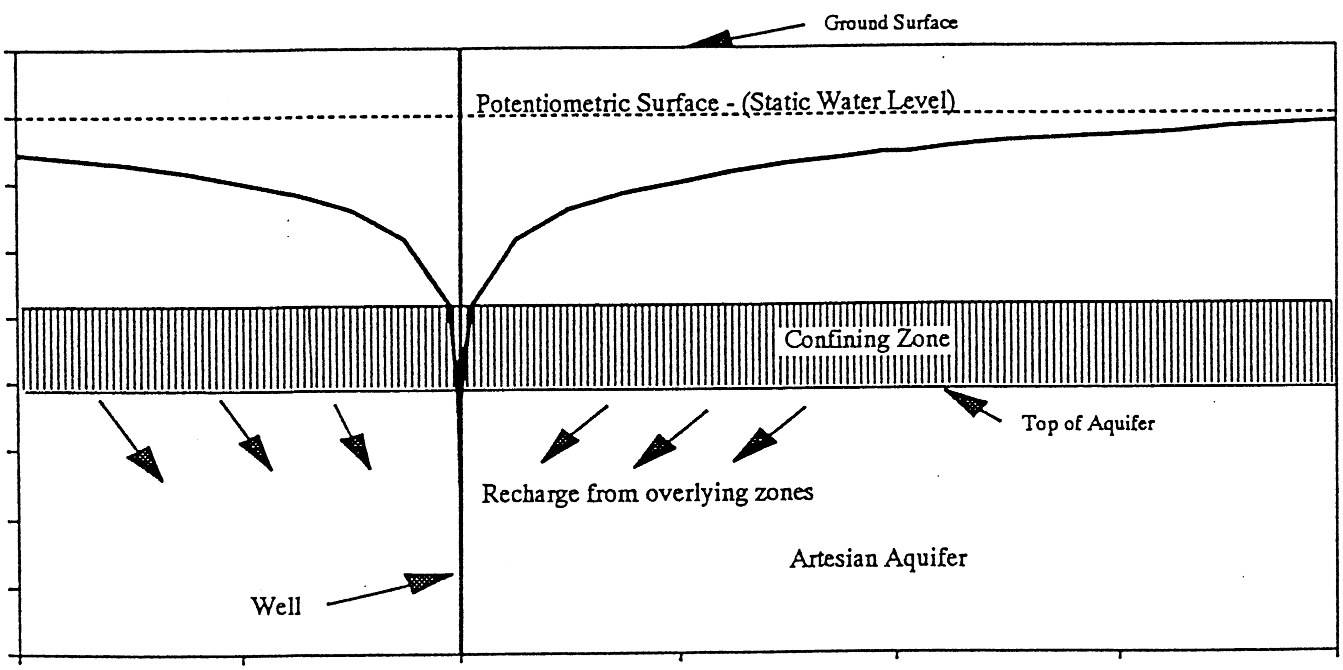
FIGURE 4.1



CONES OF DEPRESSION FOR HIGH AND LOW TRANSMISSIVITY AQUIFERS

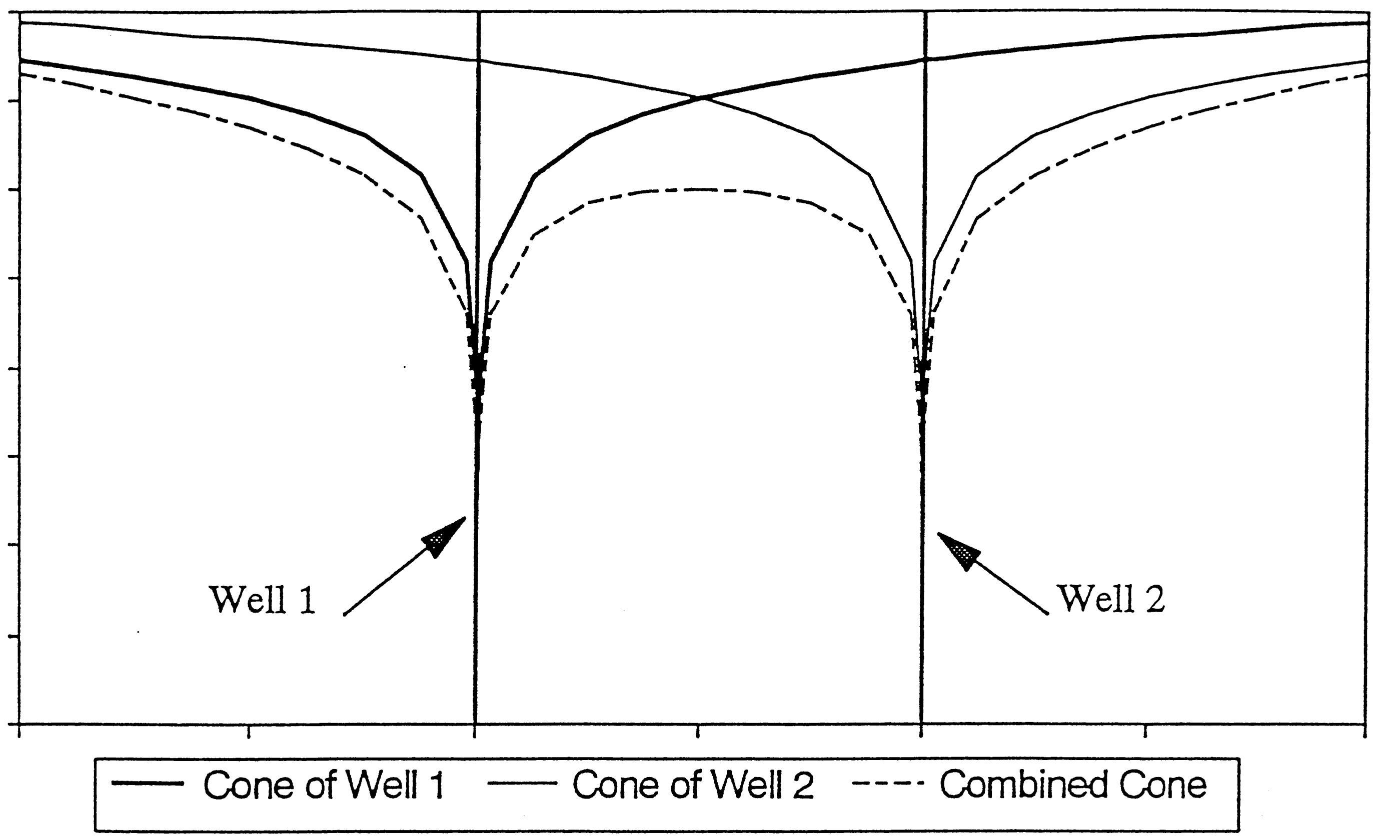
FIGURE 4.2





SOURCES OF RECHARGE TO AQUIFERS

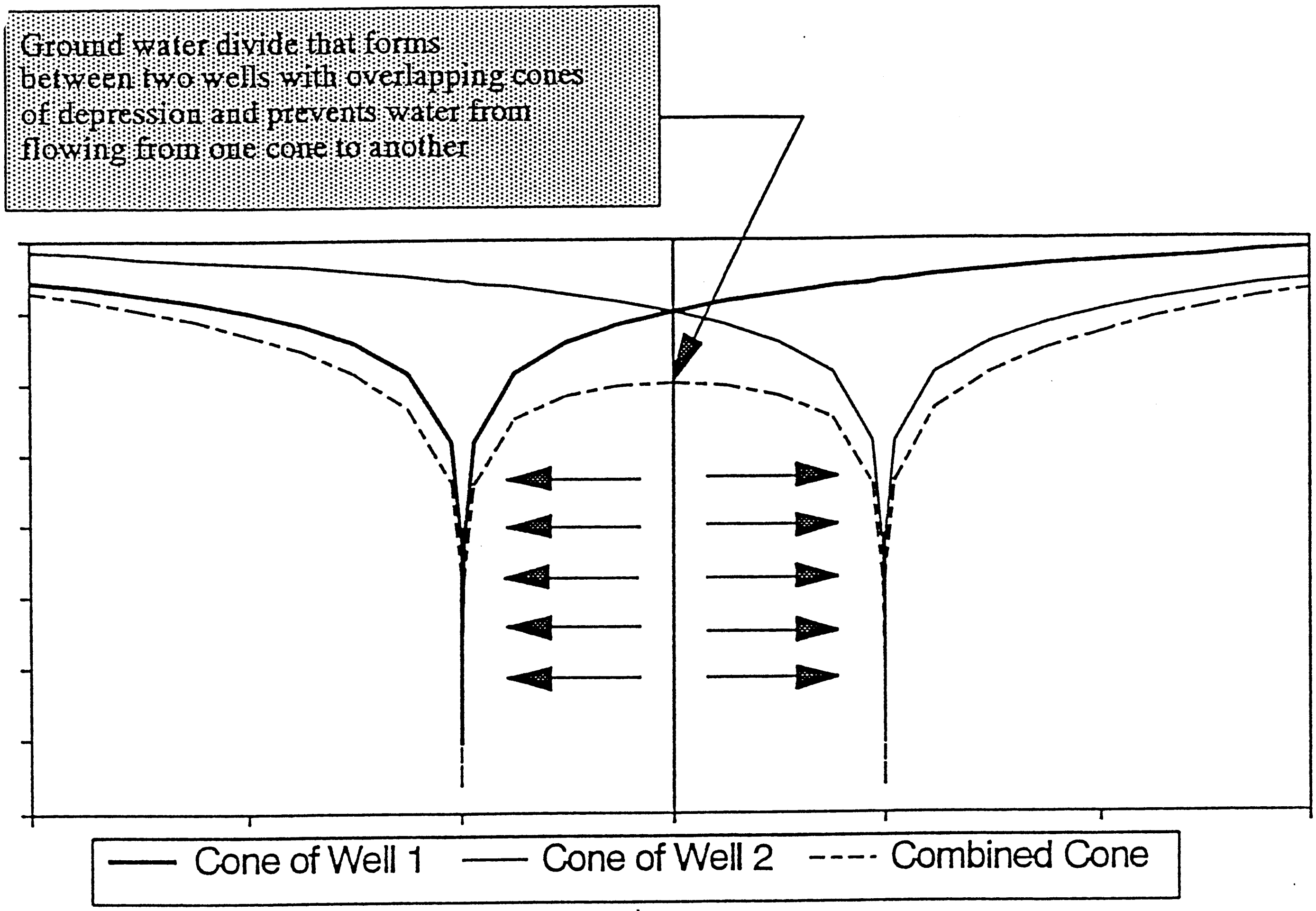
FIGURE 4.3



NOTE: TOTAL DRAWDOWN AT ANY POINT IS THE SUM OF THE DRAWDOWNS FOR EACH WELL.

DRAWDOWN THAT RESULTS WHEN CONES OF DEPRESSION OVERLAP

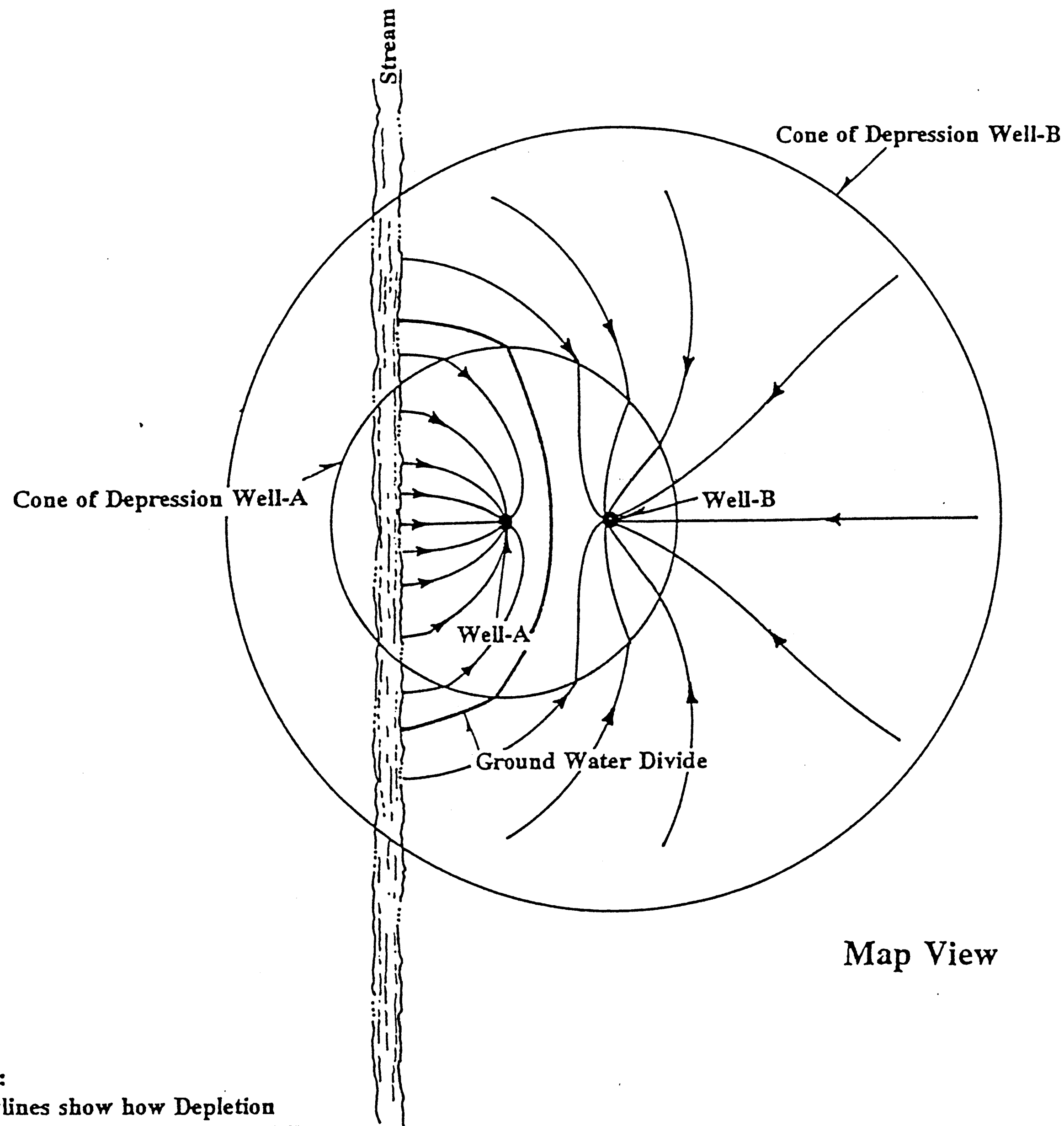
FIGURE 4.6



NOTE: TOTAL DRAWDOWN AT ANY POINT IS THE SUM OF THE DRAWDOWNS FOR EACH WELL.

GROUND WATER DIVIDE BETWEEN TWO WELLS

FIGURE 4.7



Note:
Flowlines show how Depletion from Stream Flows to each Well.

Overlapping Cones of Depression Near a Stream

Figure 4.10

IN RE THE GENERAL ADJUDICATION OF ALL RIGHTS TO USE WATER IN THE GILA RIVER SYSTEM AND SOURCE

Supreme Court Nos. WC-90-0001-IR, WC-90-0002-IR, WC-90-0003-IR, WC-90-0004-IR, WC-90-0005-IR, WC-90-0006-IR, WC-90-0007-IR, WC-79-0001, WC-79-0002, WC-79-0003, WC-79-0004.

SUPREME COURT OF ARIZONA

198 Ariz. 330*; *9 P.3d 1069*; *2000 Ariz. LEXIS 94

September 22, 2000, Filed

SUBSEQUENT HISTORY: Certiorari Denied June 25, 2001, Reported at: *2001 U.S. LEXIS 4896*.

PRIOR HISTORY: [***1] The Honorable Stanley Z. Goodfarb, Judge (Retired).

DISPOSITION: AFFIRMED.

CASE SUMMARY:

PROCEDURAL POSTURE: On return from remand, in a case involving complex general stream adjudication, the court considered whether the order of the trial court (Arizona) properly determined what underground water constituted "subflow" of a surface stream, thus making it appropriable under *Ariz. Rev. Stat. § 45-141(A)*.

OVERVIEW: The state supreme court remanded a case involving complex general stream adjudication to the trial court. On remand, the trial court entered an order defining "subflow" as the saturated floodplain Holocene alluvium, and concluding that: (1) all wells located within the lateral limits of the subflow zone were subject to the adjudication; (2) all wells located outside the subflow zone that were pumping water from a stream or its subflow, as determined by an analysis of the well's cone of depression, were included in the adjudication; and (3) wells that, although pumping subflow, had a de minimus effect on the river system might be excluded from the adjudication based on rational guidelines. When the case returned from remand, the issue before the state supreme court was whether the trial court had properly determined what underground water constituted "subflow" of a surface stream, thus making it appropriable under *Ariz. Rev. Stat. § 45-141(A)*. The state supreme court affirmed the trial court's order, because the record reasonably supported the trial court's findings, and the ruling comported with prior decisions, as well as hydrological reality.

OUTCOME: The trial court's order was affirmed, on the grounds that its findings with regards to the definition of "subflow" and the determination of which wells were pumping subflow and were thus subject to the adjudication, were reasonably supported by the record. In addition, the trial court's ruling comported with prior decisions relating to subflow, and with hydrological reality as it was currently understood.

LexisNexis(R) Headnotes

Governments > State & Territorial Governments > Water Rights
[HN1] See *Ariz. Rev. Stat. § 45-141(A)*.

Governments > State & Territorial Governments > Water Rights
Real Property Law > Water Rights > Appropriation Rights
Real Property Law > Water Rights > Groundwater
[HN2] Arizona's bifurcated system of allocating water rights differentiates groundwater users from surface water users. By statute, surface water is subject to the doctrines of prior appropriation and beneficial use. *Ariz. Rev. Stat. §§ 45-141(A), 45-251(7)*. Percolating groundwater, on the other hand, is not appropriable and may be pumped by the overlying landowner, subject to the doctrine of reasonable use and the federal reserved water rights doctrine.

Governments > State & Territorial Governments > Water Rights
[HN3] "Subflow" is defined, for legal purposes, as those waters which slowly find their way through the sand and gravel constituting the bed of the stream, or the lands under or immediately adjacent to the stream, and are themselves a part of the surface stream.

Governments > State & Territorial Governments > Water Rights
Real Property Law > Water Rights > Groundwater
[HN4] The notion of "subflow" is significant in Arizona law, for it serves to mark a zone where water pumped from a well so appreciably diminishes the surface flow of a stream that it should be governed by the same law that governs the stream. In addition, "subflow" is probably much greater in volume in some cases than the water upon the surface, and is a valuable portion of the well-defined surface stream. Because subflow is considered part of the surface stream, it is appropriable as such under *Ariz. Rev. Stat. § 45-141(A)*. Under Arizona's bifurcated system of managing surface and groundwater, the concept of subflow serves to protect appropriable surface water rights against interference caused by the pumping of groundwater. Because water is a very precious and limited commodity in Arizona, much turns on how "subflow" is determined.

Evidence > Procedural Considerations > Burdens of Proof > Clear & Convincing Proof
Governments > State & Territorial Governments > Water Rights
[HN5] Underground waters are presumed to be percolating and, therefore, not appropriable as subflow. One who asserts that underground water is a part of a stream's subflow must prove that fact by clear and convincing evidence. If the Arizona Department of Water Resources uses the proper test and relies on appropriate criteria for determining whether a well meets the test, its determination that a well is pumping appropriable subflow constitutes clear and convincing evidence. Thus, it is critical that any test used for determining the boundaries of a subflow zone be as accurate and reliable as possible. Otherwise, use of an inaccurate test to determine whether a well is pumping subflow would not satisfy the clear and convincing evidentiary standard and would improperly shift the burden to the groundwater user to show that its well is not pumping subflow.

Governments > State & Territorial Governments > Water Rights
[HN6] In almost all cases, the so-called subflow is found within, or immediately adjacent to, the bed of the surface stream itself.

Governments > State & Territorial Governments > Water Rights
[HN7] The Arizona Supreme Court has articulated the following test for determining whether a well is pumping subflow: Does drawing off the subsurface water tend to diminish appreciably and directly the flow of the surface stream? If it does, it is subflow, and subject to the same rules of appropriation as the surface stream itself; if it does not, then, although it may originally come from the waters of such stream, it is not, strictly speaking, a part thereof, but is subject to the rules applying to percolating waters.

Governments > State & Territorial Governments > Water Rights
[HN8] Tributary aquifers are those waters which infiltrate their way through the adjoining ground to some surface water course or other body of surface water. These waters differ from the subflow of surface streams in the fact that they have not yet reached the channels of the water courses to which they are tributary; while, upon the other hand, the subflow of surface streams has reached these channels and are therefore dealt with as component parts of such streams.

Governments > State & Territorial Governments > Water Rights
[HN9] A tributary aquifer is an aquifer having a direct hydraulic connection with a stream or with another aquifer that has such a connection.

Governments > State & Territorial Governments > Water Rights
Real Property Law > Water Rights > Groundwater
[HN10] Water in underground tributary aquifers is not a part of the surface stream and may not be considered subflow. Subflow and tributary groundwater are two different classes of underground water. The former is subject to appropriation; the latter is not. But, given enough time, and with certain exceptions, all extractions from a tributary aquifer will cause a more or less corresponding depletion from stream flow volume.

Governments > State & Territorial Governments > Water Rights
[HN11] Whether a well is pumping subflow does not turn on whether it depletes a stream by some particular amount in a given period of time. It turns on whether the well is pumping water that is more closely associated with the stream than with the surrounding alluvium. A proper test might compare such characteristics as elevation, gradient, and perhaps, chemical makeup of the surface stream and underground water. In addition, flow direction can be an indicator. If the water flows in the same general direction as the stream, it is more likely related to the stream.

Civil Procedure > Appeals > Standards of Review
Governments > State & Territorial Governments > Water Rights
[HN12] Although "subflow" is a purely legal, not scientific, term, defining its boundaries is not only difficult at best, but also turns ultimately on resolution of factual questions. The state supreme court, of course, must defer to the trial court's factual findings as long as the record supports them. *Ariz. R. Civ. P. 52(a).*

Civil Procedure > Appeals > Standards of Review > Clearly Erroneous Review
[HN13] See *Ariz. R. Civ. P. 52(a).*

Civil Procedure > Appeals > Standards of Review > Clearly Erroneous Review
[HN14] The trial court, not the state supreme court, weighs the evidence and resolves any conflicting facts, expert opinions, and inferences therefrom. If the record reflects that the trial court carefully and thoroughly performed those functions and then made findings that, although disputed, are fully supported by the evidence, the state supreme court will not second-guess the trial court's factual findings, but rather, will uphold them unless they are shown to be clearly erroneous. *Ariz. R. Civ. P. 52(a).*

Governments > State & Territorial Governments > Water Rights
[HN15] Variations may affect where the line is drawn between subflow and nonappropriable percolating water, depending on the volume of stream flow and other variables. Thus, defining subflow in any particular area is a relative endeavor, not an all or nothing proposition. And, although the line between surface and groundwater is, to some extent, artificial and fluid, the Arizona Supreme Court's various descriptions of subflow in prior decisions should not serve as a straitjacket that restricts the supreme court from reaching in the direction of the facts and, so far as possible under those decisions, conforming to hydrological reality.

Governments > State & Territorial Governments > Water Rights
[HN16] Prior Arizona Supreme Court decisions are not intended to establish hard and fast, artificial parameters for subflow based solely on its geographic reach or on some arbitrary distance from a streambed. Rather, the determination of whether a particular well is pumping subflow depends on whether the well is pumping water that is more closely associated with the stream than with the surrounding alluvium, and whether drawing off the subsurface water tends to diminish appreciably and directly the flow of the surface stream. That determination, in turn, necessitates a comparative evaluation of such factors as elevation, gradient, flow direction, and perhaps, chemical makeup.

Governments > State & Territorial Governments > Water Rights
[HN17] The cone of depression is the funnel-shaped area around a well where the withdrawal of groundwater through the well has lowered the water table.

Governments > State & Territorial Governments > Water Rights
[HN18] Although a cone of depression may result in only part of a well's production being appropriable subflow, that well should be included in the general adjudication.

Governments > State & Territorial Governments > Water Rights
Real Property Law > Water Rights > Groundwater
[HN19] A well pumping underground water is presumed initially to be pumping percolating groundwater, not ap-

propriable subflow. When the Arizona Department of Water Resources determines and establishes that a well is in the subflow zone by using the pertinent criteria or that it is pumping subflow by reason of its cone of depression, the department provides clear and convincing evidence of that fact. The burden then shifts to the well owner to show that a well is either outside the subflow zone or is not pumping subflow.

Governments > State & Territorial Governments > Water Rights
Real Property Law > Water Rights > Procedure
[HN20] Given the strong initial presumption that a well is pumping percolating groundwater, a preponderance of the evidence standard is more appropriate and shall apply to well owners' efforts to rebut the Arizona Department of Water Resources' determination that a well is pumping subflow. If a well owner presents sufficient evidence to meet that standard, it necessarily reduces the department's proof to something less than clear and convincing.

Governments > State & Territorial Governments > Water Rights
[HN21] Regulation of water use, enactment of appropriate laws for the wise use and management of water, and effecting any appropriate change in existing law to accommodate conflicting interests and claims of groundwater users and surface appropriators, are peculiarly legislative functions.

Civil Procedure > Appeals > Appellate Jurisdiction > Certified Questions
[HN22] The state supreme court must decide issues that are squarely presented to it, particularly when the trial court, at the parties' request, specifically certifies the questions raised in a particular matter.

Governments > Courts > Authority to Adjudicate
[HN23] The power to define existing law, including common law, and to apply it to facts rests exclusively within the judicial branch.

Governments > Courts > Authority to Adjudicate
Governments > State & Territorial Governments > Water Rights
Real Property Law > Water Rights > Beneficial Use
[HN24] Given the over quarter-century history of, and specific statutory authorization for, complex general stream adjudication, the judiciary clearly is not only empowered, but also expected to determine, based on a complete evidentiary record, issues relating to subflow. Resolution of such issues is integral to the judiciary's statutorily recognized role of determining the nature, extent, and relative priority of the water rights of all persons in the river system and source. *Ariz. Rev. Stat. § 45-252(A)*. That function, in turn, includes identification of waters of all sources flowing in streams, other natural channels, or in definite underground channels that are subject to appropriation and beneficial use. *Ariz. Rev. Stat. § 45-141(A)*. In sum, this is not an area in which the judiciary must await or necessarily defer to legislative action.

Governments > State & Territorial Governments > Water Rights
Real Property Law > Water Rights > Groundwater
[HN25] Because a well owner does not own underground water, and because landowners have no legally recognized property right in potential, future groundwater use, any constitutional argument is substantively without merit.

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JUDGES: JOHN PELANDER, Judge. CONCURRING: THOMAS A. ZLAKET, Chief Justice, STANLEY [***5] G. FELDMAN, Justice, WILLIAM E. DRUKE, Judge, NOEL FIDEL, Judge. Vice Chief Justice Charles E. Jones and Justices Frederick J. Martone and Ruth V. McGregor recused themselves; pursuant to Ariz. Const. art. VI, § 3, Judge Noel Fidel of Division One, Arizona Court of Appeals, Judge William E. Druke, and Judge John Pelander of Division Two, Arizona Court of Appeals, were designated to sit in their stead.

OPINION BY: JOHN PELANDER

OPINION

[*333] [**1072] PELANDER, Judge.

P1 This appeal again presents the second of six issues on which we granted interlocutory review in the Gila River general stream adjudication. The facts and procedural history of this case are set forth in detail in *In re the General Adjudication of All Rights* to *Use Water in the Gila River System and Source, 175 Ariz. 382, 384-86, 857 P.2d 1236, 1238-40 (1993) ("Gila River II")*, and in *In re Rights to* the *Use of the Gila River, 171 Ariz. 230, 232-33, 830 P.2d 442, 444-45 (1992)* (*"Gila River I")*. In short, the primary issue we consider here is whether, after remand in *Gila River II*, the trial court properly determined what underground water constitutes "subflow" of a surface stream, [***6] thus making it appropriable under *A.R.S. § 45-141(A)*. [1]

1 [HN1] *Section 45-141(A), A.R.S.*, states:

> The waters of all sources, flowing in streams, canyons, ravines or other natural channels, or in definite underground channels, whether perennial or intermittent, flood, waste or surplus water, and of lakes, ponds and springs on the surface, belong to the public and are subject to appropriation and beneficial use as provided in this chapter.

[**1073] [*334] P2 Based on its consideration of extensive evidence presented on remand, including the opinions of multiple experts, the trial court defined "subflow" as the "'saturated floodplain Holocene alluvium'" [2] because "the weight of the evidence" pointed to that geological unit "as the most credible 'subflow' zone." We conclude, and the parties conceded at oral argument, that the record reasonably supports that central finding as well as the trial court's related findings. We further conclude that the trial court's ruling is not invalidated by this court's prior decisions [***7] relating to subflow. See *Gila River II; Maricopa County Nun. Water Conservation Dist. No. One v. Southwest Cotton Co., 39 Ariz. 65, 4 P.2d 369 (1931)*. Finally, the ruling comports with hydrological reality as it is currently understood. See *In re the General Adjudication of All Rights to Use Water in the Gila River System and Source, 195 Ariz. 411, 415 P9, 989 P.2d 739, 743 P9 (1999) ("Gila River III")*. For these reasons, we affirm the trial court's order in its entirety.

2 "Holocene" refers to the Holocene epoch, which is that part of the Quaternary period that covers approximately the most recent 10,000 years. During that time frame, floods caused rivers to carry and deposit certain materials that originated from erosion of bedrock and basin fill deposits. The "Holocene alluvium," also referred to as the younger or floodplain alluvium, is the sedimentary material in a river valley that resulted from that process. See American Geological Institute, *Glossary of Geology* 17, 301 (Julia A. Jackson, ed., 1997).

[***8] I. GENERAL PRINCIPLES OF SUBFLOW

P3 In *Gila River II*, we explained the importance of distinguishing between groundwater and surface water. *175 Ariz. at 386, 857 P.2d at 1240*. Essentially, [HN2] our bifurcated system of allocating water rights differentiates groundwater users from surface water users. By statute, surface water is subject to the doctrines of prior appropriation and beneficial use. See *A.R.S. §§ 45-141(A), 45-251(7)*. Percolating groundwater, on the other hand, is not appropriable and may be pumped by the overlying landowner, subject to the doctrine of reasonable use, *Gila River II, 175 Ariz. at 386, 857 P.2d at 1240*; *Bristor v. Cheatham, 75 Ariz. 227, 255 P.2d 173 (1953)*, and the federal reserved water rights doctrine discussed in *Gila River III*.

P4 The boundary between surface water and groundwater is not at all clear. Most surface streams not only flow above the ground but also have "subflow." As the parties correctly point out, "subflow" is not a scientific, hydrological term. But for almost seventy years, this court has [HN3] defined "subflow," for legal purposes, as "those waters which slowly find their way through [***9] the sand and gravel constituting the bed of the stream, or the lands under or immediately adjacent to the stream, and are themselves a part of the surface stream." *Southwest Cotton, 39 Ariz. at 96, 4 P.2d at 380*. *See also Gila River II, 175 Ariz. at 390 n.9, 857 P.2d at 1244 n.9, quoting Black's Law Dictionary* 1425 (6th ed. 1990); 2 Clesson S. Kinney, *A Treatise on the Law of Irrigation and Water Rights* § 1161, at 2106-07 (2d ed. 1912) ("subflow" is "the broad and deep subterranean volume of water which slowly flows through the sand and gravel underlying most, if not all, of the streams which traverse the country adjacent to the mountain systems of the arid region").

P5 As we noted in *Gila River III*, [HN4] "the notion of 'subflow' is significant in Arizona law, for it serves to mark a zone where water pumped from a well so appreciably diminishes the surface flow of a stream that it should be governed by the same law that governs the stream." *195 Ariz. 411, 415 P8, 989 P.2d 739, 743 P8*. In addition, "subflow" is "probably much greater in volume in some cases than the water upon the surface, and [is] . . . a valuable portion of the well-defined [***10] surface stream." Kinney, *supra* at 2107. Because subflow is considered part of the surface stream, it is appropriable as such under *§ 45-141(A)*. *See Gila River II, 175 Ariz. at 387, 857 P.2d at 1241*. *See also Gila River III, 195 Ariz. 411, 415 P8, 989 P.2d 739, 743 P8*. Under Arizona's bifurcated system of managing surface and groundwater, the concept of subflow serves to protect appropriable surface water rights against interference [**1074] [*335] caused by the pumping of groundwater. Because water is a very precious and limited commodity in Arizona, much turns on how "subflow" is determined.

P6 [HN5] Underground waters are presumed to be percolating and, therefore, not appropriable as subflow. *Southwest Cotton, 39 Ariz. at 85, 4 P.2d at 376*. One who asserts that underground water is a part of a stream's subflow must prove that fact by clear and convincing evidence. *Id.* "If [the Department of Water Resources (DWR)] uses the proper test and relies on appropriate criteria for determining whether a well meets the test, its determination that a well is pumping appropriable subflow constitutes clear and convincing evidence." *Gila River II, 175 Ariz. at 392, 857 P.2d at 1246*. [***11] Thus, it is critical that any test used for determining the boundaries of a subflow zone be as accurate and reliable as possible. Otherwise, use of an inaccurate test to determine whether a well is pumping subflow would not satisfy the clear and convincing evidentiary standard and would improperly shift the burden to the groundwater user to show that its well is not pumping subflow. *See id. at 388-89, 857 P.2d at 1242-43*.

II. GILA RIVER II

P7 In *Gila River II*, we considered whether the trial court had erred "in adopting its 50%/90 day test for determining whether underground water is 'appropriable' under *A.R.S. § 45-141*." *175 Ariz. at 386, 857 P.2d at 1240*. Under that test, a well would be presumed to be pumping appropriable subflow if "the volume of stream depletion would reach 50% or more of the total volume pumped during . . . a period of withdrawal [that] is equivalent to 90 days of continuous pumping for purposes of technical calculation." *Id. at 385, 857 P.2d at 1239*. Holding that "the 50%/90 day test for identifying wells presumed to be pumping subflow is inconsistent with *Southwest Cotton* and should not be [***12] used," *id. at 392, 857 P.2d at 1246*, we vacated that portion of the trial court's order and remanded the case for the court "to take evidence and, by applying the principles contained in [the *Gila River II]* opinion, determine the criteria for separating appropriable subflow from percolating groundwater." *Id. at 394, 857 P.2d at 1248*.

P8 In so holding, we reaffirmed the principles set forth in *Southwest Cotton*, noting that our role was to interpret, not to expand or in any way change, the holdings in that case. *Id. at 389, 857 P.2d at 1243*. The *Southwest Cotton* court observed that, [HN6] "in almost all cases the so-called subflow is found within, or immediately adjacent to, the bed of the surface stream itself." *39 Ariz. at 97, 4 P.2d at 381*. [HN7] The court articulated the following test for determining whether a well is pumping subflow:

> *Does drawing off the subsurface water tend to diminish appreciably and directly the flow of the surface stream?* If it does, it is subflow, and subject to the same rules of appropriation as the surface stream itself; if it does not, then, although it may originally come from [***13] the waters of such stream, it is not, strictly speaking, a part thereof, but is subject to the rules applying to percolating waters.

Id. at 97, 4 P.2d at 380-81.

P9 In *Gila River II*, we adhered to that test and reaffirmed what we described as *"Southwest Cotton's* narrow concept of subflow." *175 Ariz. at 393, 857 P.2d at 1247*. We rejected the trial court's 50%/90 day test in part because of the potential that, under that test, all wells in an alluvial valley could be said to be pumping appropriable subflow. *Id. at 391, 393, 857 P.2d at 1245, 1247*. The 50%/90 day test was "broad enough to include all underground water hydraulically connected to a surface stream." *Id. at 391, 857 P.2d at 1245*. Thus, the test was "at odds with *Southwest Cotton's* statement that subflow is found within or immediately adjacent to the stream bed." *Id.*

P10 We discussed that problem at some length in *Gila River II*. *See 175 Ariz. at 390-92, 857 P.2d at 1244-46*. Specifically, the 50%/90 day test did not distinguish between wells pumping groundwater from tributary aquifers and those pumping actual subflow of [***14] the river. [HN8] Tributary aquifers are

> those waters which infiltrate their way through the adjoining ground to some surface water course or other body of surface [**1075] [*336] water. These waters differ from the subflow of surface streams in the fact that *they have not yet reached the channels of the water courses to which they are tributary;* while, upon

> the other hand, the subflow of surface streams has reached these channels and are therefore dealt with as component parts of such streams.

Kinney, *supra* § 1193, at 2162 (footnotes omitted) (emphasis added). *See also Gila River II, 175 Ariz. at 389 n.7, 857 P.2d at 1243 n.7* [HN9] ("A tributary aquifer is an aquifer having a direct hydraulic connection with a stream or with another aquifer that has such a connection."). [HN10] Water in underground tributary aquifers is not a part of the surface stream and may not be considered subflow. *See Gila River II, 175 Ariz. at 391, 857 P.2d at 1245* (noting that, under *Southwest Cotton,* subflow and tributary groundwater are "two different classes of underground water. The former is subject to appropriation . . .; the latter is not."). But, "given enough time, and [***15] with certain exceptions, all extractions from a tributary aquifer will cause a more-or-less corresponding depletion from stream flow volume." *Id.* Thus, under the 50%/90 day test, the water in underground tributary aquifers would have been included as subflow if the volume and time requirements were met, even though that water is specifically excluded under *Southwest Cotton.*

P11 The arbitrariness of the 50%/90 day test also influenced our decision in *Gila River II. Id. at 392, 857 P.2d at 1246*. We stated that [HN11] "whether a well is pumping subflow does not turn on whether it depletes a stream by some particular amount in a given period of time. . . . It turns on whether the well is pumping water that is more closely associated with the stream than with the surrounding alluvium." *Id.* We also suggested that a proper test might compare "such characteristics as elevation, gradient, and perhaps chemical makeup" of the surface stream and underground water. *Id.* In addition, "flow direction can be an indicator. If the water flows in the same general direction as the stream, it is more likely related to the stream." *Id.*

P12 In sum, we rejected the trial court's [***16] 50%/90 day rule because it conflicted with *Southwest Cotton* and arbitrarily set time and volume limits rather than determining the nature of the water being pumped. *Id. at 391-92, 857 P.2d at 1245-46*. In contrast, as discussed below, the order at issue here resulted from the trial court's exhaustive effort, based on application of the pertinent factors set forth in *Gila River II,* to determine "whether the well is pumping water that is more closely associated with the stream than with the surrounding alluvium." *Id. at 392, 857 P.2d at 1246*.

III. PROCEEDINGS AND ORDER AFTER REMAND

P13 On remand, the trial court held a ten-day evidentiary hearing, during which ten experts in the fields of geology and hydrology testified. The court also spent two days traveling almost 600 miles in the San Pedro River basin. A "large number of counsel" and several experts accompanied the court on that trip. At each of the thirteen sites visited, each expert was allowed to explain the geology and hydrology of the site. In its order, the trial court noted that a transcript prepared from audio tapes made on the trip "is 258 pages because at nearly every site [***17] discussion was lengthy, often at odds, and sometimes heated." In addition, statements were taken from several long-time residents of the valley "who were witnesses to facts of historical significance with regard to the river." Four months after the field trip, the trial court held a two-day supplemental evidentiary hearing, the purpose of which was to evaluate "any changes in the location or size of the principal channel of the river or the riparian vegetation areas adjacent to the river," as shown in aerial photographs taken fifty-five years apart.

P14 In its order after remand, the trial court stated:

> This Court has reviewed all of the testimony given, all of the exhibits, participated fully in the field trip and read all of the briefs. It also re-examined the testimony and exhibits of the 1987 evidentiary hearing on the relationship of groundwater to surface water. It finds a sufficient foundation of facts needed to rule on the issues presented.

[**1076] [*337] The comprehensive, detailed order itself confirms those statements. It is sixty-six pages long, with thirty-six additional pages of exhibits. The order and the record as a whole clearly reflect that the trial court allowed [***18] the parties to fully present evidence and to advocate their positions and thoughtfully considered the complex issues presented here. [3]

3 The record includes not only transcripts of the evidentiary hearings, but also numerous reports, drawings, charts, and other exhibits.

IV. DISCUSSION

A. Definition of subflow zone

P15 [HN12] Although "subflow" is a purely legal, not scientific, term, defining its boundaries is not only difficult at best but also turns ultimately on resolution of factual questions. We, of course, must defer to the trial court's factual findings as long as the record supports them. *See Ariz. R. Civ. P. 52(a), 16 A.R.S.* [HN13] ("Findings of fact . . . shall not be set aside unless clearly erroneous, and due regard shall be given to the opportunity of the trial court to judge the credibility of witnesses."); *Scottsdale Unified Sch. Dist. No 48 v. KPNX Broadcasting Co., 191 Ariz. 297, P20, 955 P.2d 534, P20 (1998)*.

P16 The trial court's order describes in detail the evidence presented [***19] at the hearings and fully explains the reasons for its conclusions. Moreover, the record reflects that the court based its ruling on evaluation of the pertinent factors set forth in *Gila River II* for delineating the subflow zone. For example, the order states:

> After consideration of flow direction, water level elevation, the gradation of water levels over a stream reach, the chemical composition if available, and lack of hydraulic pressure from tributary aquifer and basin fill recharge which is perpendicular to stream and "subflow" direction, the Court finds the most accurate of all the markers is the edge of the saturated floodplain Holocene alluvium.

P17 The trial court found that the younger Holocene alluvium "is the only stable geologic unit which is beneath and adjacent to most rivers and streams, except those in the mountains where bedrock surrounds the flow." The court then elaborated:

> Also, in order to fulfill the definition of "subflow," the geologic unit must be saturated because of the need for a hydraulic connection between the stream and the "subflow." Further definition requires "subflow" to be a part of the surrounding floodplain of the stream basin. [***20] Those parts of the alluvial plain which it may be a part of or which it is connected to must be the alluvial plain of a perennial or intermittent stream and not an ephemeral stream or a part of the alluvial plain of a tributary aquifer even if there is an alluvial connection. Where the alluvial plain of tributary aquifers or ephemeral streams connects to the floodplain Holocene alluvium of the stream itself and provides tributary or basin fill recharge, that tributary aquifer must also be excluded because its flow direction is different and often perpendicular to the stream-flow direction.
>
> The evidence here shows that the only true geologic unit which is beneath and adjacent to the stream is the floodplain Holocene alluvium. When it is saturated, that part of the unit qualifies as the "subflow" zone, where the water which makes up the saturation flows substantially in the same direction as the stream, and the effect of any side discharge from tributary aquifers and basin fill is overcome or is negligible. Because low-flow streams like the San Pedro meander back and forth in a series of "S" curves within a wider principal or dynamic channel, flow direction must be the general overall [***21] direction of the stream. As [DWR expert] Steve Erb testified, as long as the subflow's direction is within 45 degrees of that general stream flow direction, the flow direction requirement is met.
>
> If we add the following additional criteria, then even more certainty and reliability is provided. First, the water level elevation of the "subflow" zone must be relatively the same as the stream flow's elevation. Second, the gradient of these elevations for any reach must be comparable [**1077] [*338] with that of the levels of the stream flow. Third, there must be no significant difference in chemical composition that cannot be explained by some local pollution source which has a limited effect. Fourth, where there are connecting tributary aquifers or floodplain alluvium of ephemeral streams, the boundary of the "subflow" zone must be at least 200 feet inside of that connecting zone so that the hydrostatic pressure effect of the side recharge of this tributary aquifer is negligible and the dominant direction of flow is the stream direction. Fifth, where there is a basin-fill connection between saturated zones of the floodplain Holocene alluvium and a saturated zone of basin fill, [***22] the boundary of the "subflow" zone must be 100 feet inside of the connecting zone so that the hydrostatic pressure effect of the basin-fill's side discharge is overcome and the predominant direction of flow of all of the "subflow" zone is the same as the stream's directional flow. . . .

> The weight of the evidence points to the saturated floodplain Holocene alluvium as the most credible "subflow" zone. Its lateral and vertical limits have existed for some 10,000 or more years. It has far more stability of location than any other proposal including the principal channel which changes approximately every three years, or the post-1880 depositional layer which is really "post-1937" at best, or "post-1955" as indicated in the Hereford Report . . . .

P18 In sum, the trial court complied with *Gila River II* by applying the factors set forth therein to the various theories advanced by the parties. The court ultimately concluded:

> 1. A "subflow" zone is adjacent [to] and beneath a perennial or intermittent stream and not an ephemeral stream.
>
> 2. There must be a hydraulic connection to the stream from the saturated "subflow" zone.
>
> 3. Even though there may be a hydraulic [***23] connection between the stream and its floodplain alluvium to an adjacent tributary aquifer or basin-fill aquifer, neither of the latter two or any part of them may be part of the "subflow" zone.
>
> 4. That part of the floodplain alluvium which qualifies as a "subflow," beneath and adjacent to the stream, must be that part of the geologic unit where the flow direction, the water level elevations, the gradations of the water level elevations and the chemical composition of the water in that particular reach of the stream are substantially the same as the water level, elevation and gradient of the stream.
>
> 5. That part of the floodplain alluvium which qualifies as a "subflow" zone must also be where the pressure of side recharge from adjacent tributary aquifers or basin fill is so reduced that it has no significant effect on the flow direction of the floodplain alluvium. . . .
>
> 6. Riparian vegetation may be useful in marking the lateral limits of the "subflow" zone[,] particularly where there is observable seasonal and/or diurnal variations in stream flow caused by transpiration. However, riparian vegetation on alluvium of a tributary aquifer or basin fill cannot extend the [***24] limits of the "subflow" zone outside of the lateral limits of the saturated floodplain Holocene alluvium.
>
> 7. All wells located in the lateral limits of the "subflow" zone are subject to the jurisdiction of this adjudication no matter how deep or where these perforations are located. However, if the well owners prove that perforations are below an impervious formation which preclude[s] "drawdown" from the floodplain alluvium, then that well will be treated as outside the "subflow" zone.
>
> 8. No well located outside the lateral limits of the "subflow" zone will be included in the jurisdiction of the adjudication unless the "cone of depression" caused by its pumping has now extended to a point where it reaches an adjacent "subflow" zone, and by continual pumping will cause a loss of such "subflow" as to affect the quantity of the stream.

P19 As they did in the trial court, most of the groundwater users urge us to limit the subflow zone to the post-1880 entrenchment channel, which resulted from a process in [**1078] [*339] which a stream eroded downward so as to form a trench. The entrenchment channel is part of and lies within the younger alluvium. According to the groundwater users, that [***25] channel extends downward to the vertical boundary of the post-entrenchment alluvium and is laterally narrower than the younger alluvium.

P20 Relying primarily on the testimony of their principal expert, Dr. Errol Montgomery, the groundwater users contend the post-1880 entrenchment channel is a well-known, well-documented, and easily identifiable geological unit found throughout the Southwest and is the only reliable marker of the subflow zone. They argue that only that channel satisfies *Gila River II* because it is more closely related to the stream than to the surrounding alluvium, it transports underground water beneath and immediately adjacent to the surface stream, and pumping from it has a direct and appreciable impact on the stream flow.

P21 The trial court rejected the post-1880 entrenchment channel and other alternative proposals for defining the subflow zone. [4] Those who urge the post-1880 entrenchment channel as the most appropriate subflow zone essentially contend that the weight of the evidence supported that result and that the trial court misinterpreted the evidence in rejecting it.

4 Some groundwater users proposed that the subflow zone be defined by the banks or edge of the stream's principal channel. And, The Nature Conservancy proposed, inter alia, that the subflow zone should be defined by the riparian zone, that is, the geographic area that phreatophytes had occupied in predevelopment times. The trial court rejected those proposals.

[***26] P22 We note, however, that Montgomery testified that his master's thesis did not even mention or map the post-1880 entrenchment area because it would not be "called out" in most geological investigations that address the principal geological units. Rather, Montgomery stated, "it's only for special purposes, special studies that a unit like the post-1880 would be delineated." He also expressed doubt that DWR would be able to recognize the distinction. Montgomery further testified that "the boundary that can be recognized below the subsurface is going to be the boundary between the Holocene alluvium and the basin fill deposits, because there's not only a lithologic or textural change there, but there's a cementation change."

P23 In addition, other expert testimony refuted the reliability of the post-1880 entrenchment as the designation of subflow zone. For example, Steve Erb of DWR testified that, although any of the proposals presented to the trial court might possibly satisfy this courts's criteria in *Gila River II*, the younger alluvium is as close as anything to a natural boundary where subflow occurs. He further testified that DWR anticipated difficulty in identifying a subflow [***27] zone based on post-1880 entrenchment due to the lack of lithologic distinction between the ages of the younger alluvium. Similarly, Allen Gookin, who testified on behalf of the Gila River Indian Community, recommended not using the post-1880 entrenchment channel as the defining marker for subflow zone because (1) it does not occur throughout the entire Gila River basin, (2) movement of rivers over time would demand redefinition and redetermination of subflow zone on a continuing basis, and (3) there is no geological difference between the channel and the rest of the younger alluvium.

P24 Moreover, the groundwater users conceded at oral argument, and the record reflects, that sufficient evidence supports the trial court's factual findings, which adopted the saturated floodplain Holocene alluvium as the subflow zone. [5] Thus, the groundwater users' [**1079] [*340] argument largely boils down to a disagreement with the trial court's resolution of disputed facts and conflicting expert opinions. Such issues, however, are solely and peculiarly within the province of the trial court.

5 Specifically, the record, including expert testimony and reports admitted at the hearing on remand, reflects the following:

A. The saturated floodplain Holocene alluvium has a definable bed and banks and has current from the flow of underground water in response to gradient.

B. The methodology and procedure for delineating the subflow zone are not based on volume or time, but rather, on a geological feature that is a distinct, mappable, geological unit.

C. The saturated floodplain Holocene alluvium is more closely related to the stream than to surrounding alluvium, exists immediately adjacent to and beneath the stream bed, and does not extend from ridge line to ridge line. It is in direct hydraulic connection with the surface stream.

D. The groundwater table elevation in the saturated floodplain Holocene alluvium is at or near the surface of the stream.

E. Gradient and flow direction within the saturated floodplain Holocene alluvium generally are more closely associated with the river than with surrounding aquifers. The boundaries of the subflow zone set by the trial court are adequate to eliminate from the equation areas of connecting tributary aquifers, floodplain alluvium of ephemeral streams, or saturated basin fill.

F. The chemical composition of surface water and of water contained in the saturated floodplain Holocene alluvium is virtually identical.

> G. Using the saturated floodplain Holocene alluvium for identifying subflow zone is not arbitrary, but rather, is scientifically based on geology and associated aquifer characteristics.

[***28] P25 The parties presented conflicting evidence, including expert opinions, to support their theories relating to subflow and its parameters. [HN14] The trial court, not this court, weighs the evidence and resolves any conflicting facts, expert opinions, and inferences therefrom. *In re Estate of Pouser, 193 Ariz. 574, P13, 975 P.2d 704, P13 (1999)*. The record reflects that the trial court carefully and thoroughly performed those functions and then made findings that, although disputed, are fully supported by the evidence. Under these circumstances, we will not second-guess the court's factual findings, but rather, will uphold them unless they are shown to be clearly erroneous. *See Ariz. R. Civ. P. 52(a)*. No such showing has been made here.

P26 As they did in *Gila River II* with respect to the 50%/90 day rule, the groundwater users also contend the trial court's order after remand "is wrong as a matter of law" because its definition of subflow is too broad and is incompatible with *Gila River II* and *Southwest Cotton.* In support of that argument, they point to language in those opinions variously describing subflow as underground water that is "'a part of the [***29] surface stream,'" *175 Ariz. at 387, 857 P.2d at 1241, quoting Southwest Cotton, 39 Ariz. at 96, 4 P.2d at 380*; "'found within, or immediately adjacent to, the bed of the surface stream itself,'" *175 Ariz. at 387, 391, 857 P.2d at 1241, 1245, quoting Southwest Cotton, 39 Ariz. at 97, 4 P.2d at 381*; "'connected with the stream[,] . . . strictly confined to the river bottom and moving underground'" "'within the bed of the surface stream itself,'" *175 Ariz. at 390, 857 P.2d at 1244*, *quoting* Kinney, *supra* § 1161, at 2110; and "relatively close to the stream bed." *175 Ariz. at 391, 857 P.2d at 1245*. According to the groundwater users, the trial court's adoption of the saturated floodplain Holocene alluvium as the subflow zone cannot be squared with those prior pronouncements.

P27 As the groundwater users correctly observe, this court "adopted [Kinney's] narrow definition [of subflow] in *Southwest Cotton," Gila River II, 175 Ariz. at 390, 857 P.2d at 1244*, and again characterized subflow as "a narrow concept" in *Gila River II. Id. at 391, 857 P.2d at 1245*. [***30] Although those abstract, general statements hold true, we also observed in *Gila River II* that [HN15] variations may affect where the line is drawn between subflow and nonappropriable percolating water, "depending on the volume of stream flow and other variables." *Id.* Thus, defining subflow in any particular area is a relative endeavor, "not an all-or-nothing proposition." *Id.* And, although "the line between surface and groundwater . . . is, to some extent, artificial and fluid," *id. at 392, 857 P.2d at 1246*, our various descriptions of subflow in *Gila River II* and *Southwest Cotton* should not serve as a straitjacket that restricts us from reaching in the direction of the facts and, so far as possible under those decisions, conforming to hydrological reality.

P28 Our dissatisfaction with the 50%/90 day test in *Gila River II* stemmed largely from its arbitrary volume and time components, contrary to *Southwest Cotton's* mandate to define subflow "in terms of whether the water at issue was part of the stream or was percolating water on its way to or from the stream." *Gila River II, 175 Ariz. at 392, 857 P.2d at 1246*. The 50%/90 day test [***31] included no such inquiry, as the trial court [**1080] [*341] acknowledged in its subsequent order after remand: "A review of the exhibits and testimony of [the 1987] hearing reflects the issue of "subflow" or how it could be physically located was not the focus of those hearings. Rather, it was a hearing as to the general relationship of surface flow to groundwater of all types." The court further stated that, "while *[Gila River II]* is correct in that there was no substantial evidentiary basis for [the 50%/90 day rule], the reason for it was that the 1987 hearings did not focus on 'subflow.'"

P29 In contrast, the trial court's order after remand stated: "In dealing with the issue of 'subflow' as raised in 'Southwest Cotton,' the hearings held in . . . 1994 specifically focused on it. All [the] testimony related directly to that issue and the issue of 'cones of depression.'" The voluminous record confirms those statements.

P30 The resolution of this case should not hinge on the semantics used in either *Gila River II* or *Southwest Cotton* to generally describe subflow. In short, [HN16] those decisions were not intended to establish hard and fast, artificial parameters for subflow based [***32] solely on its geographic reach or on some arbitrary distance from a streambed. *See Southwest Cotton, 39 Ariz. at 87, 4 P.2d at 377* (factors relevant to determining subflow include "geologic formation"); *City of Los Angeles v. Pomeroy, 124 Cal. 597, 57 P. 585, 598 (Cal. 1899)* (facts supported jury finding that underground water flowing through a pass one and one-half to two and one-half miles wide constituted subflow), *cited with approval in Southwest Cotton, 39 Ariz. at 97-99, 4 P.2d at 381*. Rather, as we stated in *Gila River II*, the determination of whether a particular well is pumping subflow depends on "whether the well is pumping water that is more closely associated with the stream than with the surrounding alluvium," *175 Ariz. at 392, 857 P.2d at 1246*, and whether *"'drawing off the subsurface water tend[s] to diminish appreciably and directly the flow of* *the surface stream.'" Id. at 393, 857 P.2d at 1247, quoting Southwest Cotton, 39 Ariz. at 97, 4 P.2d at 380*. That determination, in turn, necessitates a comparative evaluation of such factors as "elevation, gradient, [flow [***33] direction,] and perhaps chemical makeup." *Gila River II, 175 Ariz. at 392, 857 P.2d at 1246*.

P31 Using those pertinent criteria, the trial court held extensive evidentiary hearings for the purpose of "separating appropriable subflow from percolating groundwater," *175 Ariz. at 394, 857 P.2d at 1248*, with the ultimate aim of establishing a workable and reasonably accurate definition of subflow. [6] Resolution of that issue was necessarily fact intensive. As noted above, the record reflects, and the parties now concede, that sufficient evidence supports the trial court's factual findings.

> 6 Contrary to the suggestion of some of the parties at oral argument, the trial court did not exceed the scope of this court's remand in *Gila River II.* We specifically instructed the court to "take evidence" and "apply[] the principles contained" in *Gila River II* for purposes of "separating appropriable subflow from percolating groundwater." *175 Ariz. at 394, 857 P.2d at 1248*. We did not intend to limit the trial court to merely determining useful criteria for that task.

[***34] P32 Unlike the 50%/90 day test we rejected in *Gila River II,* the trial court's order after remand is not arbitrary. Nor does it include tributary aquifers in its definition of subflow. Although the saturated floodplain Holocene alluvium may appear to be inconsistent with the "narrow concept" of subflow described in *Gila River II*, *175 Ariz. at 391*, *857 P.2d at 1245*, and suggested in *Southwest Cotton,* we reject the argument that the trial court's findings and conclusions, as a matter of law, so violate the fundamental principles of those cases that they cannot stand. Nor does affirmance of the trial court's order require us to overrule *Gila River II* or *Southwest Cotton,* and we do not do so.

P33 At oral argument, the groundwater users questioned how the "saturated" younger alluvium is to be defined and identified and what role, if any, the criteria that we set forth in *Gila River II* and that the trial court used will play in determining subflow in different locations. The criteria that the trial court articulated were elaborations of, but consistent with, the more general criteria set forth in *Gila River II.* The trial court properly [**1081] [*342] applied [***35] these criteria to the San Pedro River basin in order to determine the most appropriate subflow zone, and the weight of the evidence supports the trial court's identification of that zone as the "saturated" floodplain Holocene alluvium.

P34 The record reflects that the saturated floodplain Holocene alluvium is readily identifiable; that DWR can quickly, accurately, and relatively inexpensively determine the edge of that zone; and that some of the work already has been done. For example, the Salt River Project's (SRP) expert, Jon Ford, presented a proposal that identified subflow for the entire San Pedro River watershed and conducted a field check of his map to refine the boundaries. DWR may use such data accumulated during these proceedings to aid in its task. DWR also may use, but is not limited to, topographic maps, aerial photographs, phreatophyte presence, drilling records (or other descriptions of materials encountered during drilling), water table maps, seismic data, and field mapping techniques.

P35 The entire saturated floodplain Holocene alluvium, as found by DWR, will define the subflow zone in any given area. [7] In the effort to determine that zone in other areas, the detailed [***36] criteria set forth in the trial court's order, insofar as they apply and are measurable, must be considered, but we do not preclude the consideration of other criteria that are geologically and hydrologically appropriate for the particular location.

> 7 According to Erb, DWR does not include as part of a floodplain aquifer any area where the floodplain alluvium is above the water table.

P36 Contrary to the groundwater users' argument, the saturated floodplain Holocene alluvium does not automatically or necessarily encompass the entire younger alluvium. Equating the two would fail to take into account the pertinent criteria that must be applied and satisfied for determining the "saturated" subflow zone in a particular area. *See Southwest Cotton, 39 Ariz. at 96, 4 P.2d at 380* (noting that "the water from the surface stream must necessarily fill the loose, porous material of its bed to the point of complete saturation before there can be any surface flow"). It also would conflict with our rejection [***37] in *Gila River II* of any unqualified, blanket rule that invariably would include "all of an alluvial valley's wells" or all "waters pumped any place in the younger alluvium" in the definition of subflow. *175 Ariz. at 391, 393, 857 P.2d at 1245, 1247*. But, contrary to the groundwater users' argument that the trial court's definition of subflow is broader than *Gila River II* and *Southwest Cotton* permit, the record reflects that saturated floodplain Holocene alluvium occupies only very narrow portions of the alluvial basins.

P37 Moreover, as Ford explained and as the trial court acknowledged, the Holocene or floodplain alluvium is only the most recent portion of "stream alluvium." The entire younger alluvium is of Quaternary age, which includes materials deposited during both the Pleistocene era (approximately 1.8 million to 10,000 years ago) as well as the Holocene era (approximately the past 10,000 years to date). [8] And, as Montgomery acknowledged, modern floodplain alluvium underlies and is adjacent to nearly all large streams. Finally, the trial court's order does not preclude, but rather contemplates, future adoption of "a rationally based exclusion for wells [***38] having a de minimus effect on the river system," an approach we continue to endorse. *Gila River II, 175 Ariz. at 394, 857 P.2d at 1248. See also San Carlos Apache Tribe v. Superior Court, 193 Ariz. 195, PP35-40, 972 P.2d 179, PP35-40 (1999).*

8 According to Montgomery, Holocene describes material deposited during approximately the last 8,000 years.

B. Cones of depression

P38 The trial court's order limits the subflow zone to the saturated floodplain Holocene alluvium. Thus, wells outside that area are presumed not to be pumping subflow. The trial court ruled, however, that "wells located outside the lateral parameters of the defined 'subflow' zone" may be included in the adjudication if "it is proven that their 'cones of depression' [9] reach the [**1082] [*343] 'subflow' zone and the drawdown from the well affects the volume of surface and 'subflow' in such an appreciable amount that it is capable of measurement." In other words, the trial court ruled, a well may be subject to the adjudication [***39] if its "'cone of depression' caused by its pumping has now extended to a point where it reaches an adjacent 'subflow' zone, and by continual pumping will cause a loss of such 'subflow' as to affect the quantity of the stream."

9 [HN17] The cone of depression is the funnel-shaped area around a well where the withdrawal of groundwater through the well has lowered the water table. *Gila River II, 175 Ariz. at 391 n.10, 857 P.2d at 1245 n.10.*

P39 The trial court did not attempt to establish a test for determining a well's cone of depression because the court lacked pertinent evidence on that issue. Instead, the court recognized that each well must be separately evaluated "to compute drawdown at the 'subflow' zone" and that "whatever test ADWR finds is realistically adaptable to the field and whatever method is the least expensive and delay-causing, yet provides a high degree of reliability, should be acceptable."

P40 We agree with the trial court. DWR may seek to establish that a well located outside [***40] the limits of the saturated floodplain alluvium is in fact pumping subflow and is therefore subject to the adjudication, by showing that the well's cone of depression extends into the subflow zone and is depleting the stream. And, as we stated in *Gila River II,* [HN18] although a cone of depression may result in only part of a well's production being appropriable subflow, "that well should be included in the general adjudication." *175 Ariz. at 391, 857 P.2d at 1245.*

C. Burdens of proof

P41 The trial court's order and the parties' briefs addressed the standard of proof a well owner must meet to rebut DWR's assessment that a well is pumping subflow. As noted in P6 above, [HN19] a well pumping underground water is presumed initially to be pumping percolating groundwater, not appropriable subflow. When DWR determines and establishes that a well is in the subflow zone by using the pertinent criteria or that it is pumping subflow by reason of its cone of depression, DWR provides clear and convincing evidence of that fact. *See Gila River II,* 179 Ariz. at 392, 857 P.2d at 1246. The burden then shifts to the well owner to show that a well is either outside the subflow zone [***41] or is not pumping subflow. *Id.*

P42 In its order after remand, the trial court stated that, "at least in the area of 'cones of depression[,]' a burden of proof of preponderance seems fairer. The same is probably also true in the area of a 'subflow' zone determination." The court noted that, in determining cones of depression, experts "often rely on assumptions which are not provable or are only partially provable" and that a clear and convincing standard for rebuttal purposes probably would be "too formidable a barrier" for pro se parties and often would be "too much for represented parties of modest wealth."

P43 [HN20] Given the strong initial presumption that a well is pumping percolating groundwater, we agree with the trial court that a preponderance of the evidence standard is more appropriate and should apply to well owners' efforts to rebut DWR's determination that a well is pumping subflow. [10] If a well owner presents sufficient evidence to meet that standard, it necessarily reduces DWR's proof to something less than clear and convincing.

10 We did not state or suggest otherwise in *Gila River II.*

[***42] D. Other Issues

P44 We summarily dispose of the parties' remaining arguments relating to the trial court's determination of subflow. In *Gila River II,* we stated that [HN21] "'regulation of water use,'" enactment of appropriate laws for the "'wise use and management'" of water, and effecting "any appropriate change in existing law" to accommodate "conflicting interests and claims of groundwater users and surface appropriators," are peculiarly legislative functions. *175 Ariz. at 393, 857 P.2d at 1247*, quoting *Arizona Pub. Serv. Co. v. Long, 160 Ariz. 429, 436, 773 P.2d 988, 995 (1989)*. Based on that language, the groundwater users and the state contend that judicially [**1083] [*344] redefining subflow to encompass percolating, nonappropriable groundwater violates those principles by improperly usurping the legislative role. That argument, however, overlooks three basic points.

P45 First, for nearly seven decades, this court has established the parameters of subflow without legislative action or direction. Second, as discussed above, the trial court did not change existing law concerning subflow or otherwise improperly encroach on the state's Groundwater Code, *A.R.S. §§ 45-401 through* [***43] *45-704*. Rather, the court merely applied the criteria set forth in *Gila River II* to the evidence presented on remand. As SRP correctly notes, the trial court's order "addresses only appropriable water and wells that pump such water," without "changing the legal status of underground water that is not appropriable." Third, [HN22] this court must decide issues that are squarely presented to it, particularly when, as here, the trial court, at the parties' request, specifically certified the questions raised in this matter. *See San Carlos Apache Tribe, 193 Ariz. 195, P37, 972 P.2d 179, P37* [HN23] ("The power to define existing law, including common law, and to apply it to facts rests exclusively within the judicial branch.").

P46 [HN24] Given the over quarter-century history of, and specific statutory authorization for, this complex general stream adjudication, *see id.* at P2; *972 P.2d 179, P2*, the judiciary clearly is not only empowered but also expected to determine, based on a complete evidentiary record, issues relating to subflow. Resolution of such issues is integral to our statutorily recognized role of determining "the nature, extent and relative priority of the water rights [***44] of all persons in the river system and source." *A.R.S. § 45-252(A)*. That function, in turn, includes identification of "waters of all sources, flowing in streams, . . . other natural channels, or in definite underground channels" that "are subject to appropriation and beneficial use." *§ 45-141(A). See also § 45-251(7)*. In sum, this is not an area in which we must await or necessarily defer to legislative action. *Cf. Law v. Superior Court, 157 Ariz. 147, 155, 755 P.2d 1135, 1143 (1988)* ("We are furthering the statutory objectives in this area, not contradicting them.").

P47 We also reject the groundwater users' assertion that the trial court's order amounts to an unconstitutional taking of their private property, in violation of the Fifth Amendment. In remanding this matter in *Gila River II* for the trial court to establish an evidentiary and principled basis for differentiating appropriable subflow from percolating groundwater, we implicitly rejected the groundwater users' identical argument in that case. Moreover, [HN25] because a well owner does not own underground water, Town of *Chino Valley v. City of Prescott, 131 Ariz. 78, 82, 638 P.2d 1324, 1328 (1981)*, [***45] and because landowners have "no legally recognized property right in potential, future groundwater use," *Gila River I, 171 Ariz. at 239, 830 P.2d at 451*, the constitutional argument is substantively without merit.

V. CONCLUSION

P48 We affirm the trial court's order after remand in all respects. The subflow zone is defined as the saturated floodplain Holocene alluvium. DWR, in turn, will determine the specific parameters of that zone in a particular area by evaluating all of the applicable and measurable criteria set forth in the trial court's order and any other relevant factors. *See* PP33-35, *supra*. All wells located within the lateral limits of the subflow zone are subject to this adjudication. In addition, all wells located outside the subflow zone that are pumping water from a stream or its subflow, as determined by DWR's analysis of the well's cone of depression, are included in this adjudication. Finally, wells that, though pumping subflow, have a de minimus effect on the river system may be excluded from the adjudication based on rational guidelines for such an exclusion, as proposed by DWR and adopted by the trial court.

JOHN PELANDER, Judge

CONCURRING:

[***46] THOMAS A. ZLAKET, Chief Justice

STANLEY G. FELDMAN, Justice

WILLIAM E. DRUKE, Judge

NOEL FIDEL, Judge

Vice Chief Justice Charles E. Jones and Justices Frederick J. Martone and Ruth V. McGregor recused themselves; pursuant to [**1084] [*345] *Ariz. Const. art. VI, § 3*, Judge Noel Fidel of Division One, Arizona Court of Appeals, Judge William E. Druke, and Judge John Pelander of Division Two, Arizona Court of Appeals, were designated to sit in their stead.

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IN THE SUPERIOR COURT OF THE STATE OF ARIZONA

IN AND FOR THE COUNTY OF MARICOPA

IN RE THE GENERAL ADJUDICATION OF ALL RIGHTS TO USE WATER IN THE GILA RIVER SYSTEM AND SOURCE	W-1 (Salt) W-2 (Verde) W-3 (Upper Gila) W-4 (San Pedro) (Consolidated) CIVIL NO. W1-103 REPORT OF THE SPECIAL MASTER ON THE ARIZONA DEPARTMENT OF WATER RESOURCES' SUBFLOW TECHNICAL REPORT, SAN PEDRO RIVER WATERSHED; MOTION FOR APPROVAL OF REPORT; AND NOTICE OF SUBSEQUENT PROCEEDINGS

CONTESTED CASE NAME: *In re Subflow Technical Report, San Pedro River Watershed.*

HSR INVOLVED: None.

DESCRIPTIVE SUMMARY: The Special Master submits a report to the Court under Arizona Rule of Civil Procedure 53 pursuant to an order of reference. The report contains recommendations regarding whether the *Subflow Technical Report, San Pedro River Watershed*, prepared by the Arizona Department of Water Resources, should be adopted in whole or in part or modified. Objections to the Special Master's report must be filed with the Superior Court on or before **Wednesday, September 1, 2004**. Responses to objections shall be filed on or before **Friday, October 1, 2004**, and replies shall be filed by **Friday, October 29, 2004**.

NUMBER OF PAGES: 100; Attachment A - 4 pgs.; Total 104 pgs.

DATE OF FILING: July 16, 2004.

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Attachments

I. CHRONOLOGY OF PROCEEDINGS

This report addresses the objections filed to the *Subflow Technical Report, San Pedro* River *Watershed* (2002) ("Subflow Report") prepared by the Arizona Department of Water Resources ("ADWR").[1] ADWR filed the Subflow Report pursuant to the trial court's directive to supplement the department's prior *Report Concerning Implementation of the Arizona Supreme Court's Decision on Subflow* (2001). The reports recommend procedures to implement the subflow criteria and a cone of depression test in accordance with the Arizona Supreme Court's *Gila II*[2] and *Gila IV*[3] decisions. Those decisions, arising from the same interlocutory review appeal, deal with subflow, an issue extensively litigated in this adjudication since 1987.

The Gila River Adjudication will determine or establish "the extent and priority of the rights of all persons to use water in [the Gila] river system and source."[4] A "river system and source" includes "all water appropriable" under A.R.S. § 45-141.[5] The Arizona Supreme Court has held that

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[1] The pleadings and orders filed in the proceedings before the Special Master are available at the office of the Clerk of the Maricopa County Superior Court, 601 West Jackson Street, Phoenix, Arizona 85003, under Civil No. W1-103 (contact Tina Barrett or Veronica Olivas at 602-506-1351). Electronic copies of the orders are posted at http://www.supreme.state.az.us/wm/ on the page titled *Gila River Adjudication (In re Subflow Technical Report, San Pedro River Watershed)*.

[2] *In re the General Adjudication of All Rights to Use Water in the Gila River System and Source*, 175 Ariz. 382, 857 P.2d 1236 (1993) ("*Gila II*"). The Supreme Court framed the interlocutory review issue as, "Did the trial court err in adopting its 50%/90 day test for determining whether underground water is 'appropriable' under A.R.S § 45-141." 175 Ariz. at 386, 857 P.2d at 1240.

[3] *In re the General Adjudication of All Rights to Use Water in the Gila River System and Source*, 198 Ariz. 330, 9 P.3d 1069 (2000), *cert. denied sub nom. Phelps Dodge Corp. v. U.S.*, 533 U.S. 941 (2001) ("*Gila IV*"). In *Gila II*, the Arizona Supreme Court remanded to the trial court, which after further hearings issued a ruling whose appeal to the Supreme Court resulted in *Gila IV*. *Gila II* and *Gila IV* sought to resolve "the ambiguities and uncertainties left by" the Court's decision in *Maricopa County Mun. Water Conservation Dist. No. 1 v. Southwest Cotton Co.*, 39 Ariz. 65, 4 P.2d 369 (1931), *modified and reh'g. denied*, 39 Ariz. 367, 7 P.2d 254 (1932) ("*Southwest Cotton*"). 175 Ariz. at 389, 857 P.2d at 1243.

[4] A.R.S. § 45-251(2).

[5] A.R.S. § 45-251(7).

"[b]ecause subflow is considered part of the surface stream, it is appropriable as such under § 45-141(A)."[6] Therefore, a well pumping subflow is subject to the adjudication.

In *Gila IV*, the Supreme Court defined the subflow zone as the saturated floodplain Holocene alluvium and set forth three tests to determine if a well is subject to the adjudication because it pumps subflow:

> 1. All wells located within the lateral limits of the subflow zone are subject to this adjudication;
>
> 2. [A]ll wells located outside the subflow zone that are pumping water from a stream or its subflow, as determined by DWR's analysis of the well's cone of depression, are included in this adjudication; and
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> 3. [W]ells that, though pumping subflow, have a de minimis effect on the river system may be excluded from the adjudication based on rational guidelines for such an exclusion, as proposed by DWR and adopted by the trial court.[7]

Whether ADWR's proposed procedures to delineate the lateral limits of the subflow zone, implement a cone of depression test, and set rational guidelines for *de minimis* water uses comport with the Supreme Court's decisions are the central issues addressed in this report.

Chapter I of this report describes the proceedings. Chapters II, III, IV, and V address the issues raised in Chapters 2, 3, 4, and 5, respectively, of the Subflow Report. Chapters VI, VII, and VIII relate to future proceedings before the trial court regarding this report. The Special Master has considered all the papers, declarations, testimony, thirty-eight admitted exhibits, and oral arguments.

A. The Technical Reports

At the trial court's hearing held on September 27, 2001, counsel inquired as to ADWR's plans to propose criteria for determining the subflow zone. ADWR answered it had "internally been

[6] 198 Ariz. at 334, 9 P.3d at 1073.
[7] 198 Ariz. at 344, 9 P.3d at 1083.

discussing the issues related to developing subflow criteria."[8] The court directed ADWR to file a report describing its "proposals for determining the subflow criteria for purposes of this adjudication."[9] The court allowed parties to file responses to the report and set a hearing on January 8, 2002, to consider the report and responses.

On December 18, 2001, ADWR filed a *Report Concerning Implementation of the Arizona Supreme Court's Decision on Subflow*. The San Carlos Apache Tribe, Tonto Apache Tribe, and Yavapai-Apache Nation (collectively "Apache Tribes"); Arizona Public Service ("APS"); Phelps Dodge Corporation ("Phelps Dodge"); ASARCO Incorporated ("ASARCO"); BHP Copper, Inc. ("BHP"); Inscription Canyon Ranch; Baca Float Water Company; Cities of Chandler, Glendale, Mesa, and Scottsdale (collectively "Cities"); City of Phoenix ("Phoenix"); Gila River Indian Community ("GRIC"); Gila Valley and Franklin Irrigation Districts (collectively "Upper Valley Irrigation Districts"); Salt River Project ("SRP"); State of Arizona Agency Claimants ("State of Arizona"); United States; and The Nature Conservancy ("Nature Conservancy") filed responses to the report or joinders to others' comments.[10]

On January 8, 2002, during the hearing of ADWR's report and the responses, the trial court directed "ADWR to prepare another more specific and detailed report pertaining to the San Pedro River watershed. . . ."[11] The court's order issued later stated:

> To promote an efficient and accurate determination of the jurisdictional subflow zones, ADWR shall prepare a supplemental report specifically identifying and describing the procedures and processes it proposes to use to establish the limits of the subflow zone within the San Pedro River watershed. This report shall include the following:
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> 1. A proposal for determining the subflow zone that includes more than just consideration of the saturated lateral extent of the Holocene alluvium. The Court has

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[8] Sept. 27, 2001 Minute Entry 4 (Oct. 25, 2001).
[9] *Id*.
[10] Several parties filed jointly, but each party will be listed separately in this report.
[11] Jan. 8, 2002 Minute Entry 2 (Jan. 22, 2002).

considered ADWR's position that the decision of the Arizona Supreme Court in "Gila IV" requires that the subflow zone be initially delineated by simply mapping the saturated lateral limits of the floodplain of this alluvium. Many claimants object to this procedure and assert that AWDR's current proposal is not legally sufficient. The Court notes that the guidelines set forth in Gila IV direct ADWR to use all criteria geologically and hydrologically appropriate for subflow determination in each watershed. Even if ADWR is correct about the tasks mandated by Gila IV to determine the subflow zone, the work required to address the other considerations mentioned in Gila IV will serve to confirm the accuracy of ADWR's determinations. Therefore, in determining the subflow zone in the San Pedro River watershed ADWR shall use a methodology that addresses the appropriate use, if any, of each of the criterion listed in Gila IV, as well as any other relevant factors that will be helpful in insuring that ADWR's subflow zone determination is completed using all reasonable means to arrive at results that are as accurate as possible;

2. A test for determining if a well's cone of depression is withdrawing water from the subflow zone;

3. A set of rational guidelines for determining whether a given well, though pumping subflow, has a de minimis effect on the river system;

4. A method for including both perennial and intermittent streams as part of the subflow analysis, including streams that historically contained perennial or intermittent flows, but which now are ephemeral due to development and other human initiated actions. The Court recognizes this direction makes ADWR's task more complicated and expects the department to formulate a proposal using readily available historical data that will permit determination of water levels and locations as of date(s) prior to widespread diversion and depletion of Arizona's stream flows. Effluent-fed streams are also to be included as part of ADWR's analysis; and

5. A timeline for completion of the tasks outlined in the report. A similar timeline for the Upper Gila River and Verde River watersheds is also to be submitted.

ADWR's supplemental report shall be filed on or before March 29, 2002 and shall contain a certification by the ADWR Director that he has read and is familiar with the proposal set forth in the report.

After the report is filed, claimants and parties shall have until May 13, 2002 [*note: on May 7, 2002, upon motion, the Court granted additional time to respond until June 17, 2002*] to file objections or requested revisions to the report. These comments may be presented by legal memorandum, exhibits and/or sworn declarations of experts.

After receipt of all timely filed objections, the Court will review ADWR's proposal and party comments. It is likely the Court will enter an order after this review directing ADWR as to how it is to proceed. Should the Court determine that further information or explanation is needed, the matter will be referred [to] the Special

Master for hearing. The declarations submitted by the parties will serve as the direct testimony at any hearing scheduled by the Special Master. The only testimony to be received at any scheduled hearing will be by way of cross-examination (and, perhaps, some limited redirect examination).[12]

On March 29, 2002, ADWR filed the Subflow Report. The report sets forth ADWR's proposed procedures to delineate the lateral extent of the subflow zone, implement a cone of depression test, establish guidelines for *de minimis* water uses, and schedules to implement the methodologies in the Gila River Adjudication.[13]

On June 17, 2002, comments, objections, and joinders were filed by the Apache Tribes; Arizona Geological Survey; APS; Phelps Dodge; ASARCO; Arizona Water Company; Bella Vista Water Company ("Bella Vista"); BHP; Cities; City of Flagstaff; City of Safford ("Safford"); DYM, Inc.; Painted Rock Ranches; Paloma Ranch Investments, Inc. ("Paloma Ranch"); Rio Rico Properties, Inc. ("Rio Rico"); Tonopah Irrigation District ("Tonopah"); GRIC; Upper Valley Irrigation Districts; City of Goodyear; George E. Price on behalf of the Long Meadow Ranch Property Owners Association; City of Benson; Valory Strausser individually and on behalf of Lower San Pedro River Landowners; Phoenix; SRP; State of Arizona; United States; City of Sierra Vista ("Sierra Vista"); City of Tucson ("Tucson"); City of Sedona, Town of Jerome, Town of Clarkdale, City of Cottonwood, and Town of Camp Verde (collectively "Verde Valley Communities"); Verde Valley Water Users Association, Inc. by officers and directors Ray Wrobley, Mary Margaret Kovacovich, and John Kovacovich; and the County of Yavapai.

The following expert witnesses filed sworn declarations on June 17, 2002:

1. Kirk C. Anderson, Ph.D. (Upper Valley Irrigation Districts).

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[12] Minute Entry (Jan. 22, 2002) ("Ballinger Order").

[13] The report has six chapters: Chapter 1 Introduction; Chapter 2 Subflow Zone; Chapter 3 Cone of Depression; Chapter 4 *De Minimis* Uses; Chapter 5 Summary and Implementation; and Chapter 6 References Cited. The attachments include one table, five figures, six plates, and nine appendices. An electronic copy of the report is posted at http://www.water.az.gov under *Publications* and *Adjudications*.

2. Philip C. Briggs, P.E. (Verde Valley Water Users Association, Inc. by officers and directors Ray Wrobley, Mary Margaret Kovacovich, and John Kovacovich).

3. Jon R. Ford (SRP).

4. T. Allen J. Gookin, P.E., R.L.S., P.H. (GRIC).

5. Eric J. Harmon, P.E. and Mark R. Palumbo (APS and Phelps Dodge).

6. W. Gerald Matlock, P.E., Ph.D. (Upper Valley Irrigation Districts).

7. Peter A. Mock, Ph.D., R.G. (GRIC).

8. Errol L. Montgomery, Ph.D., P.G. and Thomas W. Anderson, P.H. (BHP).

9. Oliver S. Page, R.G., Peter M. Pyle, R.G., C.Hg., and Jean M. Moran, R.G., C.Hg. (United States).

10. Doug Toy, P.E. (Cities).

B. Order of Reference to the Special Master

Following a hearing held on January 22, 2003, the trial court referred "the consideration of the responses and objections filed to the Subflow Report to the Special Master," who "[a]fter reviewing the matter and holding such hearings as he deems necessary…shall prepare a report to the Court setting forth his recommendations as to whether the Subflow Report should be adopted in whole or in part or modified."[14] The order of reference did not direct the Special Master to make findings of fact and conclusions of law.[15]

C. Issues Set for Briefing and Hearing

On April 10, 2003, the Special Master held a conference to discuss the scope of the Special Master's report and establish procedures to comply with the order of reference. SRP, Upper Valley

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[14] Order 1 (Feb. 21, 2003).

[15] Ariz. R. Civ. P. 53(h) states, "The master shall prepare a report upon the matters submitted to the master by the order of reference and, if required to make findings of fact and conclusions of law, the master shall set them forth in the report." This matter does not involve the determination of any individual water uses.

Irrigation Districts, and the Verde Valley Communities submitted proposed issues for resolution. APS and Phelps Dodge filed comments to the proposed issues.

The Special Master considered all the comments and proposed issues, and on April 25, 2003, issued an order:

1. Setting the following issues for briefing prior to the cross-examination of witnesses:

a. Should ADWR's subflow analysis consider predevelopment or current stream flow conditions?

b. Should ADWR consider the criteria specified in *Gila IV* to identify the subflow zone or have the criteria already been taken into account in the Arizona Supreme Court's holding that the saturated floodplain Holocene alluvium is the subflow zone?

c. In addition to analyzing a well's drawdown at the subflow zone, should ADWR report the cumulative effect of wells or of groups of wells?

d. Should ADWR's findings be reported in supplemental contested case hydrographic survey reports (HSRs) ("case-by-case") or in a supplemental San Pedro River Watershed HSR ("the entire watershed"), which identifies the subflow zone, wells reaching and depleting a stream, and *de minimis* water rights?

2. Allowing parties to file sworn rebuttal declarations on or before June 27, 2003, limited to rebutting the opinions or information contained in the initial sworn declarations and not presenting any new matters not contained in those declarations.

3. Setting a hearing for the cross-examination of witnesses on October 21 and 22, 2003.

4. Directing that the cross-examination of witnesses would address, but would not be limited to, the following matters:

Location of Subflow Zone

a. Are ADWR's recommendations for locating perennial, intermittent, and effluent-fed streams valid?

b. Does ADWR's recommendation that the entire lateral extent of the floodplain Holocene alluvium be assumed to be saturated comport with *Gila IV*?

c. Is ADWR's recommended assumption for effluent-fed streams "that the sediments immediately beneath these reaches are unsaturated due to clogging layers" valid?

d. Are ADWR's recommendations sufficient to identify and exclude tributary aquifers and basin fill saturated zones?

Cone of Depression Test

a. Does ADWR's recommended drawdown of greater than or equal to 0.1 foot, where the cone of depression has reached the edge of the subflow zone, comport with *Gila IV*?

b. Does ADWR's recommended condition that the water level in a well be below the water level in the subflow zone during pumping comport with *Gila IV*?

c. What is the accuracy and reliability of analytical (THWELLS) and numerical (MODFLOW) models for the cone of depression test?

d. Is ADWR's recommendation that the impact of a well be measured "*at the time of the modeling*" scientifically valid?

e. Should ADWR recommend a methodology to evaluate the impact of wells perforated below an impervious formation within the limits of the subflow zone?[16]

The Special Master indicated the four issues set for briefing would be ruled upon prior to the cross-examination of the expert witnesses. Memoranda, responses, and replies were filed between June 6, 2003, and August 11, 2003. Oral argument was not set.

D. Discovery

A discovery issue arose prior to the submission of briefs. The United States requested clarification of permissible discovery after being served with a request for documents by the Upper Valley Irrigation Districts. The request sought copies of forty documents listed by the United States' expert witnesses in their credentials.

On August 7, 2003, the Special Master issued an order stating that formal discovery of other than the disclosure of the sworn declarations, by means of depositions, interrogatories, production of

[16] Special Master's Order Setting Briefing Schedule and Hearing 3-4 (Apr. 25, 2003).

documents or things, inspections, examinations, and requests for admissions was not contemplated in this proceeding, but informal discovery of not more than eight reports described or listed in the declarations would be allowed. Informal discovery was to be completed by October 7, 2003.

E. Rebuttal Declarations

On June 27, 2003, the following expert witnesses filed rebuttal declarations:

1. Mr. Briggs (Verde Valley Water Users Association, Inc. by officers and directors Ray Wrobley, Mary Margaret Kovacovich, and John Kovacovich).

2. Mr. Ford (SRP).

3. Mr. Gookin (GRIC).

4. Messrs. Harmon and Palumbo (APS and Phelps Dodge).

5. Mr. Michael J. Lacey (Bella Vista and Pueblo Del Sol Water Company ("Pueblo Del Sol")).

6. Mr. Ralph P. Marra, Jr. (Tucson).

7. Dr. Mock (GRIC).

8. Dr. Matlock (Upper Valley Irrigation Districts, Verde Valley Communities, and the Maricopa-Stanfield and Central Arizona Irrigation and Drainage Districts).

9. Dr. Montgomery and Mr. Anderson (BHP).

10. Messrs. Page and Pyle (United States).

11. Mr. Toy (Cities).

F. Special Master's Proposed Rulings

On September 8, 2003, the Special Master issued proposed rulings for the four issues briefed prior to the hearing. The order stated the rulings "may be modified in accordance with relevant testimony, credible evidence, or persuasive argument presented during the examination of witnesses on October 21 and 22, 2003."[17]

The issues and a summary of the rulings are as follows:

Issue 1: Should ADWR's subflow analysis consider predevelopment or current stream flow conditions?

1. ADWR's subflow analysis shall consider predevelopment stream flow conditions.

2. The date of predevelopment shall be a chronological year or a range of years immediately prior to widespread diversion and depletion of the stream's flows as a result of any human activity.

Issue 2: Should ADWR consider the criteria specified in *Gila IV* to identify the subflow zone or have the criteria already been taken into account in the Arizona Supreme Court's holding that the saturated floodplain Holocene alluvium is the subflow zone?

1. The criteria specified in *Gila IV* to identify or delineate the subflow zone have already been taken into account in the Arizona Supreme Court's holding that the saturated floodplain Holocene alluvium is the subflow zone.

2. If ADWR is unable by using the means it proposes to identify or delineate the subflow zone in a stream segment, ADWR is directed to use the criteria specified in *Gila IV* and any other relevant factors that are appropriate for the particular location to delineate the subflow zone.

Issue 3: In addition to analyzing a well's drawdown at the subflow zone, should ADWR report the cumulative effect of wells or of groups of wells?

1. A well's drawdown at the subflow zone shall be analyzed individually for each well.

2. The Special Master will not decide in this order whether ADWR should report the cumulative effect of wells or of groups of wells. A ruling will be made after considering the evidence presented at the October hearing.

Issue 4: Should ADWR's findings be reported in supplemental contested case hydrographic survey reports (HSRs) ("case-by-case") or in a supplemental San Pedro River Watershed HSR ("the entire watershed"), which identifies the subflow zone, wells reaching and depleting a stream, and *de minimis* water rights?

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[17] Special Master's Order Determining Issues 1 Through 4, 11 (Sept. 8, 2003).

1. The Special Master recommends the following schedule for the San Pedro River Watershed:

A. After the Superior Court adopts or modifies the Special Master's report recommending the procedures and processes to delineate the subflow zone within the San Pedro River Watershed and a cone of depression test, ADWR is directed to prepare a map delineating the subflow zone for the entire San Pedro River Watershed. ADWR shall submit this map and related information in a technical report and not in any form of HSR. The scope of the technical report shall be limited to delineating the subflow zone.

B. Upon filing its technical report with the Superior Court, ADWR shall send a notice to all claimants in the San Pedro River Watershed and the parties listed in the Gila River Adjudication Court-Approved Mailing List informing them of the scope and availability of the report and of a claimant's right to file written objections to the report and of the deadline for filing objections.

C. Any claimant in the San Pedro River Watershed may file a written objection to ADWR's technical report within 120 days of the date on which the report was filed. Objections shall be limited to ADWR's findings regarding the subflow zone.

D. After considering the objections, the Superior Court will approve the map that delineates and establishes the subflow zone for the San Pedro River Watershed.

E. Using the cone of depression test adopted by the Superior Court, ADWR will analyze wells located outside the lateral limits of the subflow zone to determine if the well's cone of depression reaches an adjacent subflow zone, and if continuing pumping will cause a loss of such subflow as to affect the quantity of the stream. ADWR will examine the other water right claims to determine *de minimis* water rights in the San Pedro River Watershed in accordance with the Superior Court's September 26, 2002, order. ADWR will investigate and supplement, as needed, its findings reported in the 1991 Final San Pedro River Watershed HSR.

F. ADWR publishes a Supplemental Final San Pedro River Watershed HSR reporting its findings on a claim by claim basis, in accordance with A.R.S. § 45-256(B), including wells withdrawing subflow, cone of depression analyses, *de minimis* water rights, and all other updated information.

G. ADWR shall send a notice of the filing of the Supplemental Final San Pedro River Watershed HSR to all claimants in the Gila River Adjudication, who may file objections within 180 days of the date on which the report was filed.

2. The Special Master will direct ADWR to file the supplemental contested case HSR for *In re Fort Huachuca* after the Superior Court has approved the map delineating the subflow zone for the San Pedro River Watershed.

3. The Special Master recommends that this schedule be adopted for all the watersheds in the Gila River Adjudication subject to modifications that may be proper as a result of experience with this process.[18]

G. ADWR's Proposed Use of Soil Surveys and Expert Declarations

On September 25, 2003, ADWR filed a notice stating it had recently become aware of soil survey maps published for a portion of Cochise County that ADWR believes should be used to determine the lateral limits of the subflow zone. ADWR proposes to use the soil survey maps, prepared under the auspices of the Natural Resources Conservation Service ("NRCS") (part of the United States Department of Agriculture) working with other federal, state, and local agencies, to delineate the lateral extent of the subflow zone. The soil survey maps would be used instead of the surficial geology maps described in section 2.4 of the Subflow Report. ADWR indicated that soil survey maps will in the future be available for the entire San Pedro River Watershed and for other areas of the Gila River Adjudication.

The *Soil Survey of Cochise County, Arizona, Douglas-Tombstone Part* (2002) was based on major field work, cropland mapping, and rangeland mapping completed in 2000.[19] The "soil survey is an inventory and evaluation of the soils in the survey area" that "can be used to identify the potentials and limitations of each soil for specific land uses and to help prevent construction failures caused by unfavorable soil properties."[20] The 734-page report describes 152 soil map units within the survey area. One unit was not mapped because the landowner denied access. The report contains maps of the soil units with the classification of the soil series and their morphology found within each unit. Appendix A of ADWR's notice contains copies of several pages of the report that describe how the survey was completed.

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[18] *Id*.
[19] An electronic copy of the report is posted at http://www.water.az.gov under *Publications* and *Adjudications*.
[20] ADWR Notice of Recently Published Soil Survey Maps for Cochise Co. app. A (NRCS Soil Survey Report 187) (Sept. 25, 2003) ("ADWR Notice of Recently Published Soil Survey Maps").

ADWR proposes to use NRCS survey AZ671 to delineate the lateral extent of the floodplain Holocene alluvium along the San Pedro River between the International Border and St. David, Arizona. ADWR submitted soil survey maps covering the Hereford, Fairbank, and Land 7.5-minute Quadrangles for this river segment (Appendices C, D, and E, respectively). The State Soil Scientist provided the approximate geologic age of each soil unit shown on the three maps (Appendix F).

On October 8, 2003, APS and Phelps Dodge requested additional time to analyze and submit expert testimony on ADWR's proposed use of the soil surveys. BHP, Casa Grande, and the Verde Valley Communities filed joinders to the motion. SRP and the United States opposed the motion. During the conference held on October 10, 2003, the Special Master stated he would take up the request after the hearing.

At the conclusion of the hearing on October 22, 2003, the Special Master granted the request for additional time. The ruling was memorialized in an order issued on October 28, 2003. The order allowed parties to file sworn declarations that would "serve as the direct testimony of the expert witness if a hearing is held," and to file sworn rebuttal declarations "limited to rebutting the opinions or information contained in the sworn declarations filed on or before December 8, 2003, and shall not present any new matters not contained in those declarations."[21] A hearing to cross-examine the expert declarants was not set or held.

The following experts filed sworn declarations on December 8, 2003:

1. Marshall P. Brown, P.E. (Cities).

2. Mr. Ford (SRP).

3. Mr. Gookin (GRIC).

4. Mr. Harmon (APS and Phelps Dodge).

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[21] Special Master's Order Allowing Filing of Sworn Declarations Regarding the Proposed Use of Soil Surveys 2 (Oct. 28, 2003).

5. Dr. Mock (GRIC).

6. Dr. Montgomery (BHP).

7. Mr. Page (United States).

The Upper Valley Irrigation Districts, Casa Grande, and the Verde Valley Communities filed joinders to Mr. Harmon's declaration.

On January 12, 2004, Mr. Ford (SRP), Mr. Gookin (GRIC), Dr. Mock (GRIC), and Mr. Page (United States) filed sworn rebuttal declarations. At the October 21, 2003, hearing, ADWR presented the direct testimony of Richard T. Burtell, P.G. regarding the proposed use of the soil surveys.

H. Prehearing Proceedings

On October 8, 2003, the Special Master held a telephonic conference "to consider any matters that will facilitate the orderly and efficient conduct of cross-examination at the hearing set on October 21 and 22, 2003."[22] Procedural matters and two prehearing motions were taken up during the conference. A deadline was set to file responses to (1) the request of APS and Phelps Dodge for additional time to analyze and submit expert testimony on ADWR's proposed use of the soil surveys, and (2) a motion in limine filed a week earlier. A request to reschedule the cross-examination of witnesses was denied. Parties were directed to premark exhibits, exchange copies of exhibits, and reintroduce as a new exhibit any exhibit that had been introduced during a prior hearing in this adjudication. ADWR was requested to present additional information in the form of direct testimony regarding the proposed use of the soil surveys.

On October 3, 2003, the Upper Valley Irrigation Districts, Casa Grande, Central Arizona Irrigation and Drainage District, and the Verde Valley Communities filed a Motion in Limine to Exclude All Expert Testimony Re Legal Issues and To Exclude T. Allen J. Gookin's Rebuttal

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[22] Special Master's Order Setting Prehearing Telephonic Conference 2 (Sept. 29, 2003).

Reports and Testimony. ASARCO filed a joinder. APS, Phelps Dodge, and the State of Arizona supported the motion, which the Apache Tribes, GRIC, SRP, and the United States opposed. The movants argued that Messrs. Ford, Gookin, and Page, and Dr. Mock had in their declarations stated opinions on legal issues, or outside their areas of expertise, or beyond the scope allowed by the Special Master.

At the start of the hearing on October 21, 2003, the Special Master granted the motion in part and denied it in part. The ruling announced in open court was as follows:

> 1. None of the sworn declarations, reports, and affidavits will be excluded in its entirety on the grounds of inadmissibility of expert opinions on questions of law, opinions outside the scope of the expert's competency, and relevance.
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> 2. The Special Master will determine the weight and credibility to give to a sworn declaration, report, affidavit, or testimony that states an expert's understanding or views of a legal opinion or holding.
>
> 3. Any sworn declaration or testimony that in the opinion of the Special Master rises to the level of being a conclusion of law will be disregarded.
>
> 4. Any testimony that is based on pure speculation or conjecture will be disregarded.
>
> 5. Little, if any, weight would be given to any testimony about perceived inequities in Arizona's or other states' water laws, the future of Arizona's water laws or water resources management, the unstated intent and goals of court decisions, judges, and statutes, and how the Arizona Supreme Court should have or could have defined the subflow zone differently than it did in *Gila IV*.[23]

On October 14, 2003, reiterating an oral request made during the telephonic conference, GRIC filed a Motion for Reciprocal Treatment of All Expert Witness Reports, Declarations, Rebuttal Declarations, Affidavits, and/or Testimony with Regard to the October 3, 2003, Motion In Limine. The Upper Valley Irrigation Districts and the Verde Valley Communities opposed the motion. At the hearing on October 21, 2003, the Special Master adopted the ruling on the motion in limine as the

[23] Hrg. Tr. 11:17-12:11 (Oct. 21, 2003).

ruling on this motion and granted GRIC's motion to the extent that the relief requested was granted in the ruling on the motion in limine.

I. Participation of the Verde Valley Water Users, Inc.

Mr. Ray Wrobley, Ms. Mary Margaret Kovacovich, and Mr. John Kovacovich, "as officers and directors of Verde Valley Water Users, Incorporated, an Arizona non-profit corporation," filed a response to the Subflow Report which included Mr. Briggs' sworn declaration.[24] During the October 10, 2003, telephonic conference, Phoenix objected that because the corporation is neither a claimant nor a party in the Gila River Adjudication it should not be allowed to participate in this proceeding.

The Verde Valley Water Users, Inc. has not filed a statement of claimant in this adjudication. Mr. Wrobley, Ms. Kovacovich, and Mr. Kovacovich have, however, filed statements of claimant for their individual water uses.[25] After further discussion, counsel for the Verde Valley Water Users, Inc. stated that "he did not object to Mr. Briggs' testimony being offered on behalf of the persons who filed the statements of claimant listed in the filings of Mr. Briggs' declarations."[26]

The issue was again taken up at the end of the first day of hearing. No evidence was presented showing that the Verde Valley Water Users, Inc. has been served with a summons or has filed a statement of claimant in this adjudication. The adjudication statutes provide that only a "claimant" "may file written objections" to ADWR's reports, "have a fair and reasonable opportunity to present evidence in support of or in opposition to [ADWR's] recommendations," and "may enter into agreements regarding the attributes, satisfaction or enforcement" of water rights in relation to

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[24] Verde Valley Water Users, Inc.'s Response 1 (June 17, 2002).

[25] At the conference, it was unclear who had filed the statements of claimant listed in the response. At the hearing, it was clarified that these individuals have filed claims, and the correct numbers are for Mr. Wrobley 39-05-55886, and for Ms. Kovacovich and Mr. Kovacovich 39-05-50030 through 39-05-50034, inclusive.

[26] Special Master's Corrected Minute Entry 2 (Oct. 16, 2003).

other claimants.[27] Under the pretrial orders in this adjudication a claimant is a person who has filed a statement of claimant.[28] A corporation which has not been served a summons or has not filed a statement of claimant may not participate as a party in the adjudication. The Special Master ruled that Mr. Briggs would be allowed to testify on behalf of Mr. Wrobley, Ms. Kovacovich, and Mr. Kovacovich as individual claimants but not on behalf of the corporation.[29]

J. Hearing

The Apache Tribes, APS, Phelps Dodge, Bella Vista, Pueblo Del Sol, BHP, Cities, GRIC, Upper Valley Irrigation Districts, Verde Valley Communities, Mr. Wayne D. Klump, Mr. Ray Wrobley, Ms. Mary Margaret Kovacovich, Mr. John Kovacovich, Safford, Paloma Ranch, Rio Rico, Tonopah, SRP, Tucson, and the United States participated in the cross-examination of the expert witnesses. Thirty-eight exhibits were admitted. The order of appearance of the expert witnesses was as follows:

On October 21, 2003: 1. Richard T. Burtell, P.G. (ADWR).
2. Dale A. Mason (ADWR).
3. Dr. Montgomery (BHP).
4. Mr. Page (United States).
5. Dr. Matlock (Upper Valley Irrigation Districts).

On October 22, 2003: 6. Mr. Ford (SRP).
7. Mr. Briggs (Mr. Wrobley, Ms. Kovacovich, and Mr. Kovacovich).
8. Mr. Gookin (GRIC).
9. Mr. Harmon (Phelps Dodge).

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[27] A.R.S. §§ 45-256(B) and 45-257(C).

[28] *See* Gila River Adjudication Pretrial Orders No. 4 (Jan. 24, 2000) and 5 (Mar. 29, 2000); *see also* Rules for Proceedings Before the Special Master §§ 1.04 (definition of "claimant") and 1.16 (definition of "parties").

[29] Hrg. Tr. 240:15-19 (Oct. 22, 2003).

10. Mr. Toy (Cities).

11. Dr. Mock (GRIC).

12. Mr. Lacey (Bella Vista and Pueblo Del Sol).

13. Mr. Marra (Tucson).

K. Posthearing Proceedings

On December 8, 2003, the Upper Valley Irrigation Districts, Verde Valley Communities, and Casa Grande requested to cross-examine Mr. Burtell of ADWR regarding the proposed use of the soil surveys and to allow the parties to present legal arguments and their positions.

On January 28, 2004, the Special Master denied the request to cross-examine Mr. Burtell for the reasons that claimants had prior opportunities to file expert declarations and rebuttal declarations regarding ADWR's proposed use of the soil surveys, and the expert witnesses who had submitted declarations had available to them ADWR's proposal, Mr. Burtell's testimony, and the extensive testimony and evidence presented in this matter. The Special Master ruled that sufficient evidence had been presented regarding the appropriateness of using the soil surveys as proposed by ADWR.

The request for parties to present legal arguments and their positions on all the proposed procedures was granted. Parties were allowed to file memoranda, responses, and replies on any issue arising from ADWR's recommended procedures and on any of the proposed rulings issued on September 8, 2003. Oral argument was set on May 20, 2004.

The following parties filed a brief or a joinder: Apache Tribes, State of Arizona, APS, Phelps Dodge, ASARCO, Arizona Water Company, Tucson Electric Power Company, Bella Vista, Pueblo Del Sol, Sierra Vista, Cities, GRIC, Safford, Paloma Irrigation and Drainage District, Rio Rico, Roosevelt Water Conservation District ("Roosevelt"), SRP, Upper Valley Irrigation Districts, Verde

Valley Communities, Maricopa-Stanfield Irrigation and Drainage District, Central Arizona Irrigation and Drainage District, Casa Grande, and the United States.

Prior to the last day to file responses, SRP filed objections and a motion for expedited consideration of its request to exclude eleven exhibits attached to the Cities' opening brief. The Special Master took up the request on an expedited basis, and on April 7, 2004, granted in part and overruled in part SRP's objections to the exhibits. The objections to five exhibits and a portion of one exhibit were overruled on the grounds the Special Master had already considered the exhibits as the documents were first filed on June 17, 2002. The objections to three exhibits were overruled, but the consideration the Special Master would give to these exhibits was limited to a specific issue on which the Cities offered argument. The objections to two exhibits were granted on the grounds they were cumulative evidence.

On May 20, 2004, oral argument lasting almost two and one-half hours was heard, after which the matter was deemed submitted.

II. SUBFLOW ZONE (Chapter 2 of the Subflow Report)

A. Are ADWR's recommendations for locating perennial, intermittent, and effluent-fed streams valid?

The trial court directed ADWR to propose:

> A method for including both perennial and intermittent streams as part of the subflow analysis, including streams that historically contained perennial or intermittent flows, but which now are ephemeral due to development and other human initiated actions. The Court recognizes this direction makes ADWR's task more complicated and expects the department to formulate a proposal using readily available historical data that will permit determination of water levels and locations as of date(s) prior to widespread diversion and depletion of Arizona's stream flows. Effluent fed streams are also to be included as part of ADWR's analysis.[30]

[30] Ballinger Order 2.

ADWR proposes to identify perennial, intermittent, and effluent-fed streams in the Gila River Adjudication area by using information contained in eleven streamflow maps and several technical reports. The published maps and reports identify predevelopment perennial streams and recent perennial and intermittent streams. ADWR was unable to find a published map that shows predevelopment intermittent streams.

The predevelopment perennial streams are shown in the Hydrologic Investigations Atlas ("Atlas," 1986) compiled by the United States Geological Survey ("USGS"). The recent perennial and intermittent streams are depicted on maps prepared by the Arizona Game and Fish Department ("AGFD") dated 1981, 1993, and 1997. ADWR plans to combine information contained in these sources to create a composite map of predevelopment and recent perennial and intermittent streams.

Using the surface water quality rules of the Arizona Department of Environmental Quality ("ADEQ"), ADWR identified three major and 21 minor "effluent dependent waters" within the Gila River system, including two reaches in the San Pedro River Watershed.[31]

In its June 30, 1994, order regarding subflow, the trial court adopted from ADWR's Technical Assessment[32] these definitions of "perennial," "intermittent," and "ephemeral" streams:

> Perennial streams discharge water continuously through the year. Their source of supply is normally comprised of both direct runoff from precipitation events or snow melt, and baseflow derived from the discharge of groundwater into the stream.
>
> Intermittent streams discharge water for long periods of time, but seasonally. For example, an intermittent stream may flow all winter, every winter, but never flow continuously during the summer. During seasons when baseflow is maintained, groundwater is contributing to the stream. During seasons of discontinuous streamflow, natural and cultural losses may be greater than the contribution from groundwater, resulting in a losing stream. Or, the amount of groundwater discharge itself may have decreased due to natural or cultural uses.

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[31] Subflow Report, app. D; *see* Ariz. Admin. Code R18-11-113 (Effluent Dependent Waters).

[32] *Technical Assessment of the Arizona Supreme Court Interlocutory Appeal Issue No. 2 Opinion* (Dec. 15, 1993, ADWR) ("Technical Assessment").

> Ephemeral streams discharge water only in response to precipitation events or snowmelt, and do not have a baseflow component at any time of the year; they flow out sporadically. The groundwater system and surface water system do not establish a hydraulic connection in these systems.[33]

Gila IV affirmed the trial court's order "in its entirety" and "in all respects."[34]

Dr. Mock recommended that the definitions of perennial and intermittent streams be refined by limiting intermittent streams to those which are "groundwater-fed," and by "arbitrarily" defining a perennial stream as one that flows "at least 11 months out of each year," and an intermittent stream as one flowing "at least one month per year and less than 11 months per year of flow."[35] He posited that "[f]or this adjudication, we are only interested in groundwater-fed intermittent streams," and "arbitrary but useful thresholds of time [will] allow ADWR to make expedient progress in their analysis."[36]

There has not been a judicial determination that the Gila River Adjudication is, or should be, only interested in groundwater-fed intermittent streams. An intermittent stream may be spring-fed or in high altitude areas carry flows from melting snow. Second, adoption of time frames to classify streams could render determinations indefensible due to arbitrariness. Furthermore, the fact these definitions were provided to the trial court in a technical report addressing subflow warrants recognition that ADWR considered generally accepted hydrology principles when it submitted these definitions.

There is general agreement that the maps ADWR selected to identify perennial, intermittent, and effluent-fed streams are a good start, but the maps have limitations that require ADWR to

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[33] Order 23-24 (June 30, 1994) ("Goodfarb Order") quoting the Technical Assessment 6, 9.
[34] 198 Ariz. at 334, 344, 9 P.3d at 1073, 1083.
[35] Peter A. Mock Decl. 17 (June 17, 2002).
[36] *Id*.

undertake additional verification. Limitations include the quality of the sources of information and inconsistencies, inaccuracies, and omissions in the maps.

Regarding the USGS Atlas, Dr. Montgomery and Mr. Anderson declared that:

> [S]everal of these maps were based chiefly on observations recorded in journals of pioneers traveling through the area, early government survey field notes, and initial hydrologic investigations for selected basins. Some of the reports are from casual observations recorded by nonprofessionals whose reliability for technical observations has not been established; others represent only a single point in time and possibly only a limited reach of a stream.[37]

Regarding the AGFD maps, Mr. Page declared that:

1. There are inconsistencies in the 1993 and 1997 AGFD maps, and "[v]erification is needed where reaches are not classified and where definitions in the AGFD classification vary somewhat from that of the Trial Court;"

2. "A more precise definition of the dates of data collection would be helpful" to understand the 1993 and 1997 AGFD maps because overlaps of perennial and intermittent streams appear in two areas in the San Pedro River Watershed, and the dates "may represent the report or map publication date, rather than the date the data actually represents;" and

3. A 1997 AGFD report relied on by ADWR indicates some stream segments are "in dispute," but these "are not shown or discussed in the ADWR report and need to be clarified."

4. A 1998 AGFD map of perennial and intermittent reaches "differ[s] significantly from the 1993 and 1997 AGFD stream classifications for the San Pedro River, suggesting that the classifications are subject to change due to seasonal variation, short term climatic cycles, effects of development or other factors. Some discussion of the cause of variations affecting the length and permanence of each reach is needed to define the uncertainty associated with the classifications."[38]

Dr. Montgomery and Mr. Anderson declared that ADWR should carefully review certain reaches along the Santa Cruz River near Tucson because these reaches "are indicated to contain perennial or intermittent flow when, in fact, they previously were reported to be ephemeral flow reaches."[39]

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[37] Errol L. Montgomery and Thomas W. Anderson Decl. 11 (June 17, 2002).
[38] Oliver S. Page, Peter M. Pyle, and Jean M. Moran Decl. 6-7 (June 17, 2002).
[39] Errol L. Montgomery and Thomas W. Anderson Decl. 12 (June 17, 2002).

Mr. Gookin identified twelve rivers and creeks and one wash that "historic documentation indicates…were, in fact, live rivers," but under ADWR's methodology they would not be classified "as perennial and/or intermittent."[40] He declared that ADWR needs to obtain additional historical evidence to classify these streams. Dr. Mock expressed the same view.[41]

ADWR is aware the maps it has identified do not show some current perennial stream reaches, that intermittent reaches currently exist that were not previously identified as perennial, and that some intermittent reaches depicted on the 1997 AGFD map are "questionable" and are believed to be ephemeral based on recent stream gage data. The maps and reports ADWR has identified are a very good start, but additional work must be done to locate perennial, intermittent, and effluent-fed streams with more accuracy and reliability. The work could be as narrow as verifying stream segments. The tasks could include searching the literature for additional historical and current maps and reports; examining notices of appropriation recorded in county recorders' offices; reviewing court records of prior decrees; reviewing geological reports; field investigations; and interpreting aerial photography.

In this work, ADWR must be guided by *Gila IV's* holding that "it is critical that any test used for determining the boundaries of a subflow zone be as accurate and reliable as possible."[42] The trial court likewise directed ADWR to "arrive at results that are as accurate as possible."[43]

Recommendation 1: The Court should direct ADWR to use the definitions of perennial, intermittent, and ephemeral streams set forth in the trial court's June 30, 1994, order.

Recommendation 2: The Court should direct ADWR to investigate additional sources, including historical and current documents, scientific reports, mapping projects, aerial photography,

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[40] T. Allen J. Gookin Decl. sec. 1 at 3, 2 (June 17, 2002).
[41] Peter A. Mock Decl. 13-14 (June 17, 2002).
[42] 198 Ariz. at 335, 9 P.3d at 1074; *see* 175 Ariz. at 388-9, 857 P.2d at 1242-3.
[43] Ballinger Order 2.

and field investigations to locate perennial, intermittent, and effluent-fed streams with as much accuracy and reliability as possible.

B. Is ADWR's recommended assumption for effluent-fed streams that were not previously perennial, or recently perennial or intermittent, "that the sediments immediately beneath these reaches are unsaturated due to clogging layers"[44] valid?

In its directions to ADWR, the trial court directed that "[e]ffluent fed streams are also to be included as part of ADWR's analysis."[45] In the Subflow Report, ADWR lists three major and 21 minor "effluent dependent waters" within the Gila River system, including two reaches in the San Pedro River Watershed.

ADWR proposes that for effluent-fed streams that were not previously perennial, or recently perennial or intermittent, "it be assumed that the sediments immediately beneath these reaches are unsaturated due to clogging layers."[46] Therefore, these streams would not undergo subflow analysis. According to ADWR, "it is common for low permeability" clogging layers to be formed by the "elevated nutrient and/or organic content of most effluent," and as layers form along the bed of effluent-fed streams, the layers "can restrict the seepage of streamflow and, as a result, can cause the sediments beneath the stream to be unsaturated."[47] Bouwer's textbook is cited for the observation that clogging "is primarily a surface phenomenon that rarely extends more than 10 cm [*note: approximately 4 inches*] into the soil and often is restricted to the top centimeter or less [*note: less than ½ inch*]."[48] The "area adjacent to and beneath such streams would not, by definition, be

[44] Subflow Report 9.
[45] Ballinger Order 2.
[46] Subflow Report 9.
[47] *Id*. at 8.
[48] *Id*. at 9 quoting H. BOUWER, GROUNDWATER HYDROLOGY (McGraw-Hill 1978).

characteristic of a jurisdictional subflow zone due to the lack of a hydraulic connection between the subflow and the stream."[49]

ADWR further states, "[d]etailed geologic and hydrologic data are needed to confirm the presence or absence of clogging layers along effluent fed streams, and the occurrence of unsaturated flow beneath these streams. The Department believes these data are generally unavailable at this time and would require considerable time and resources to collect in the future."[50]

The basis of the assumption is "the lack of a hydraulic connection" between an effluent-fed stream and the subflow. Mr. Gookin declared that "[s]tudies have suggested that effluent does tend to lead to plugging, which restricts, but does not eliminate the recharge to the groundwater."[51] In his opinion, a clogging layer acts as a restriction only during one of four conditions, namely, periods of low flow and when the water table is below the stream. As for the other three conditions:

> If the water table is up to the river, then water flows from the groundwater into the river, and the muck at the bottom of the river does not form an appreciable restriction.… The third and fourth conditions are periods of high flow with and without a high water table. During periods of greater than normal flow, due to storm run off or some other event, this layer of muck is rapidly scoured away and recharge immediately begins in large amounts, if the aquifer has room to accept the water. These recharge amounts can be huge. Further, once the flood has passed, it takes time for this effluent plugging to occur again. During that time, the low flow will continue to recharge. <u>I am unaware of any situation where effluent has caused recharge to cease in a natural environment. It slows it down. It does not stop it</u>.[52] (Emphasis added.)

According to Mr. Gookin, there is a hydraulic connection between an effluent-fed stream and the subflow, which can be greater than normal during periods of high flow and varies under other conditions. This opinion accords with ADWR's description that clogging layers have "low permeability" (rather than being impermeable).

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[49] Subflow Report 9.
[50] *Id*.
[51] T. Allen J. Gookin Rebuttal Decl. ch. IX, 2 (June 27, 2003).
[52] *Id*.

In *Gila II*, the Supreme Court approved the trial court's adoption of "reasonable simplifying assumptions" which would facilitate the conclusion of the adjudications.[53] The assumption proposed for effluent-fed streams due to clogging layers is not reasonable because it cannot be concluded that there is a lack or absence of hydraulic connection in effluent-fed reaches between the stream and the subflow. The evidence that there is no hydraulic connection due to clogging layers is not conclusive.

Recommendation 3: The Court should not adopt ADWR's assumption for effluent-fed streams that were not previously perennial, or recently perennial or intermittent, that the sediments immediately beneath these reaches are unsaturated due to clogging layers.

C. Should ADWR use the soil survey maps prepared by the Natural Resources Conservation Service to delineate the lateral limits of the subflow zone?

ADWR's proposed use of the NRCS soil survey maps to delineate the subflow zone modifies Section 2.4 of the Subflow Report. In that section, ADWR proposed using the best available Holocene maps to delineate the lateral extent of the floodplain Holocene alluvium. ADWR believes that the NRCS soil survey maps are a better tool. The proposal raised four principal objections:

1. The maps include soil types "that are of mixed alluvial fan, floodplain, or stream terrace origin, not definitively of floodplain origin."[54]

2. The maps include soil types which are not associated with Holocene alluvium.

3. The maps include ephemeral streams.

4. The maps contain little site-specific information regarding depth, saturation, or aquifer characteristics because soil profiles are described down to 60 inches.

The first two objections are evident in two of the 7.5-minute quadrangle maps ADWR prepared to show the soil survey units. Mr. Burtell testified that the Hereford Quadrangle shows

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[53] 175 Ariz. at 394, 857 P.2d at 1248.
[54] Eric J. Harmon Soil Surveys Decl. 3 (Dec. 8, 2003).

areas of (1) floodplain alluvium of Holocene age and (2) "mixed floodplain and alluvial fan materials of Holocene age," and both areas "would be considered for at least determining where the subflow zone is."[55] In the Land Quadrangle,[56] Mr. Burtell identified "relic fan deposits" that have been preserved within the channel of the San Pedro River, and described an "island" of material that is "either not of Holocene age or if it is, it's not related to floodplain deposits."[57] The soil survey map shows that the "island" Mr. Burtell described in the Land Quadrangle (in Soil Unit 2) consists of "Pre-Pleistocene to Holocene Non-Floodplain Deposits," and another island on the same map (in Soil Unit 35) is identified as "Pleistocene Stream Deposits and Non-Floodplain Deposits of Various Ages."[58]

Mr. Harmon declared that of the eleven soil map units ADWR had identified "as being definitive of the floodplain Holocene alluvium," seven are associated with alluvial fans in addition to floodplains, and two units are associated with stream terraces.[59] "Alluvial fans are distinctly different from floodplain alluvium."[60] The soil survey maps, in short, (1) show the presence of Pre-Pleistocene, Pleistocene, Holocene non-floodplain, and non-floodplain deposits of various ages within the areas ADWR will investigate to determine the lateral extent of the subflow zone, and (2) in some areas do not distinguish between floodplain and alluvial fan deposits.

A group of parties argues that the subflow zone includes all of the floodplain alluvium deposited by a river or stream and not just the portion that is of Holocene age. Accordingly, the floodplain alluvium may contain Pleistocene deposits and not just Holocene alluvium. Other parties

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[55] Hrg. Tr. 25:18-26:1 (Oct. 21, 2003); ADWR Notice of Recently Published Soil Survey Maps, app. C.
[56] ADWR Notice of Recently Published Soil Survey Maps, app. E.
[57] Hrg. Tr. 27:17-20 (Oct. 21, 2003).
[58] ADWR Notice of Recently Published Soil Survey Maps, app. E.
[59] Eric J. Harmon Soil Surveys Decl. 6 (Table 1), 7 (Dec. 8, 2003); *see also* Marshall P. Brown Soil Surveys Decl. ¶¶ 10-12 (Dec. 8, 2003).
[60] Marshall P. Brown Soil Surveys Decl. ¶ 10 (Dec. 8, 2003).

argue that *Gila IV* explicitly affirmed the trial court's ruling that the subflow zone is the saturated floodplain Holocene alluvium, and therefore, the subflow zone cannot include Pleistocene deposits.

After considering the opinions of the parties and their experts, the trial court ruled:

> Throughout the hearings, field trip and later briefing, the parties have used the terms Holocene, younger alluvium, and floodplain alluvium interchangeably. This Court believes the proper terminology for the geologic unit which defines "subflow" is the "saturated floodplain Holocene alluvium." That term is used deliberately.[61]

The court noted the potential difficulty of discerning different materials:

> While the depositional processes were somewhat different, where [the Holocene or younger alluvium and the basin fill] meet it is sometimes difficult to discern the differences between one type of eroded, depositional debris from another, particularly when they may both be saturated and water bearing…. However, only the younger Holocene alluvium can pass the test of "subflow" as it is the only stable geologic unit which is beneath and adjacent to most rivers and streams, except those in the mountains where bedrock surrounds the flow.[62]

The trial court clearly stated subflow is found within the floodplain Holocene alluvium. The classification "Holocene" is uniformly used throughout its order to describe the floodplain alluvium associated with subflow. *Gila IV* affirmed the trial court's rulings in their entirety. The Supreme Court defined the term "Holocene" to refer "to the Holocene epoch, which is that part of the Quaternary period that covers approximately the most recent 10,000 years. During that time frame, floods caused rivers to carry and deposit certain materials that originated from erosion of bedrock and basin fill deposits…."[63] The trial court's rulings and *Gila IV* cannot be interpreted to mean anything other than the floodplain Holocene alluvium is where ADWR must start to delineate the lateral limits of the subflow zone.[64]

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[61] Goodfarb Order 56.
[62] *Id*.
[63] 198 Ariz. at 334 n.2, 9 P.3d at 1073 n.2.
[64] "The entire saturated floodplain Holocene alluvium, as found by DWR, will define the subflow zone in any given area." 198 Ariz. at 342, 9 P.3d at 1081.

ADWR may find areas where it will be "difficult to discern the differences" between materials, and in those, it must exercise its best technical analysis and evaluation to delineate the lateral extent of the floodplain Holocene alluvium. If other materials such as Pleistocene or relic fan deposits are found, ADWR should report their presence and extent.

The third main objection is that the soil survey maps include ephemeral streams. Mr. Harmon declared that Soil Unit 123 in the Fairbank Quadrangle is "associated with streams that are partly ephemeral and partly perennial."[65] Mr. Brown listed seven ephemeral washes whose alluvium "has been inappropriately delineated as saturated floodplain Holocene alluvium associated with the San Pedro River."[66] Mr. Ford identified fourteen ephemeral tributaries whose inclusion in the subflow zone is questionable.[67] The parties and other experts who filed declarations agree that under *Gila IV* the ephemeral streams shown on the soil survey maps must be excluded from the subflow analysis.[68]

The fourth main objection is that the NRCS used soil borings to define and map the soil types, but the boreholes generally did not exceed three to four feet and only in exceptional situations went down six or seven feet. The soil maps, therefore, contain little site-specific information about depth, saturation, or aquifer characteristics in the floodplain Holocene alluvium.

This objection evinces a concern that the soil survey maps will be used as the exclusive means to delineate the lateral limits of the subflow zone. The Special Master has previously stated, "[i]t is clear from the evidence heard that there is no single or exclusive available indicator that

[65] Eric J. Harmon Soil Surveys Decl. 8 (Dec. 8, 2003) (quoting the NRCS Soil Survey Report 156).
[66] Marshall P. Brown Soil Surveys Decl. ¶ 14 (Dec. 8, 2003).
[67] Jon R. Ford Soil Surveys Decl. ¶ 8 (Dec. 8, 2003).
[68] The exclusion of ephemeral streams is discussed in chapter 2, section G, and an exception is described in chapter 2, section E, of this report.

delineates the subflow zone as defined in *Gila IV*. Delineating the entire subflow zone in a watershed will require using more than one indicator."[69]

The Special Master adheres to this view, and the experts stated similar opinions. Mr. Brown declared, '[i]t may be appropriate to use soil survey results as a supplemental resource to assist in delineation of the saturated floodplain Holocene alluvium," but they "should not be used as the primary basis…."[70] Mr. Ford "agree[s] with the use of NRCS soil data as an additional source of data to be used to delineate the Subflow Zone, but [does] not support the use of NRCS soil data as the exclusive delineation method."[71] Dr. Mock declared the maps "would serve as but a supplemental source of data for some interpretations."[72] Dr. Montgomery opined the maps "should be used in conjunction with other maps and resources previously identified by" ADWR.[73] Mr. Page declared that "the soil information can and should be used as one of many tools."[74]

Although the NRCS surveys evaluate soils for purposes of land use planning and management, the surveys can provide useful information to delineate the subflow zone. The surveys "collect data on erosion, droughtiness, flooding, and other factors that affect soil uses and management." The surveys may not qualify as the exclusive indicator to delineate the lateral limits of the floodplain Holocene alluvium in accordance with *Gila IV*, but they should be used as they contain relevant and useful information.

ADWR specifically recommends that certified NRCS survey AZ671, released in 2003, be used to determine the lateral extent of the floodplain Holocene alluvium along the San Pedro River between the International Border and St. David, Arizona. The Hereford, Fairbank, and Land

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[69] Special Master's Order 2 (Jan. 28, 2004).
[70] Marshall P. Brown Soil Surveys Decl. ¶ 20 (Dec. 8, 2003).
[71] Jon R. Ford Soil Surveys Decl. ¶ 13 (Dec. 8, 2003).
[72] Peter A. Mock Soil Surveys Decl. 3 (Dec. 8, 2003).
[73] Errol L. Montgomery Soil Surveys Decl. 4 (Dec. 8, 2003).
[74] Oliver S. Page Soil Surveys Decl. 9 (Dec. 8, 2003).

Quadrangles are part of survey AZ671. The survey includes soil maps for most of the Babocomari River and stream reaches within Ramsey, Garden, and Miller Canyons.

Mapping

Before ADWR presented its proposal to use the NRCS soil survey maps, some experts pointed out limitations of the surficial geology maps ADWR proposed to use to delineate the lateral extent of the subflow zone. Because ADWR may consult some or all of these maps as additional sources of information, those concerns are addressed.

First, ADWR proposes to utilize four criteria to evaluate the adequacy of the surficial maps, for the areas with perennial and intermittent streams, which delineate floodplain Holocene alluvium: field work, map coverage, dating methods, and map scale. Mr. Page recommended that mapping methods be added to the selection criteria. Mapping methods include aerial photography analysis, geomorphic (topographic map) interpretation, phreatophyte mapping, and infrared image interpretation. The recommendation is appropriate.

Second, Messrs. Harmon, Palumbo, Anderson, and Page commented on map scale. They favor using larger scale maps than ADWR proposes and agree that a scale of 1:24,000 is the preferred scale. Concerning ADWR's proposed use of the Pool and Coes map[75] to delineate the floodplain Holocene alluvium within the Sierra Vista Subwatershed, Messrs. Harmon and Palumbo declared:

> The Pool and Coes map is published at a scale of 1:135,000…. In our experience, using a map at this scale does not provide sufficient detail to allow accurate determination of a geologic contact on the ground. If ADWR's proposal to use the Pool and Coes map is adopted, we believe this will lead to inaccurate conclusions regarding the location of the edge of the jurisdictional subflow zone…. [A] better choice of map for use in defining the subflow zone would be the published USGS

[75] D. R. Pool and A. L. Coes (USGS, 1999).

1:24,000 topographic map series. These maps provide a significantly more detailed scale, with one mile being depicted as 2.64 inches.[76]

Mr. Anderson declared, "[i]f I were given the task of accurately and reliably identifying the Holocene alluvium, I would attempt to locate a map focused on the Holocene alluvium with a scale of 1:24,000 (or larger, even 1:12,000) because the level of detail provided by such maps is probably necessary to identify the different surficial deposits."[77] Mr. Ford recommended "DWR should obtain large-scale draft mapping (typically at a scale of 1 inch = 2,000 feet)…. Once a particular map is selected, DWR should obtain the largest scale version of that map that is available."[78]

The recommendation that ADWR should obtain the largest scale version of a map whenever possible is appropriate. When area is the same, a large scale map will show items in greater detail than a small scale map. The Special Master will not recommend a minimum or maximum map scale, as the decision is within ADWR's professional judgment.

Third, Mr. Ford recommended that ADWR "should take special care in ensuring that the edge of the Holocene alluvium is properly transferred from the authors' published or draft mapping, so that it is accurately re-projected to the current datum used on the DWR base maps."[79] Any substantial error in transferring or re-projecting a depiction from a surficial map to ADWR's base map will negate the department's efforts to select the proper map. The NRCS report contains a similar caution, if large copies of the soil survey maps are made: "Enlargement of these maps, however, could cause misunderstanding of the detail of mapping. If the maps are enlarged, distortion will occur. Enlarged

[76] Eric J. Harmon and Mark R. Palumbo Decl. 10-11 (June 17, 2002).
[77] Kirk C. Anderson Decl. ¶ 6 (June 17, 2002).
[78] Jon R. Ford Decl. ¶ 11a (June 17, 2002).
[79] *Id*. at ¶ 11b.

maps do not show the small areas of contrasting soils that could have been shown at a larger scale."[80] The recommendation regarding technical mapping is appropriate.

The experts who submitted declarations concerning the soil surveys provided technical information, and some addressed characteristics in specific soil units. *Gila IV's* invitation is pertinent and should be accepted: "DWR may use such data accumulated during these proceedings to aid in its task."[81]

Recommendation 4: The Court should adopt ADWR's proposal to use the NRCS soil survey maps to delineate the lateral extent of the floodplain Holocene alluvium but should direct ADWR to use the maps as one source or indicator - but not the exclusive means - to delineate the lateral limits of the subflow zone.

Recommendation 5: The Court should direct ADWR to limit its subflow analysis to the floodplain Holocene alluvium. If other deposits or materials (such as Pleistocene) are found within the floodplain alluvium of a stream, the presence and extent of those deposits shall be reported, but the criterion is the floodplain Holocene alluvium.

Recommendation 6: The Court should direct ADWR to exclude from the subflow analysis the ephemeral streams shown on the NRCS soil survey maps.

Recommendation 7: The Court should adopt ADWR's proposal to use NRCS survey AZ671 as a source of information to determine the lateral extent of the floodplain Holocene alluvium in the San Pedro River and its reaches between the International Border and St. David, Arizona.

Recommendation 8: The Court should direct ADWR to consider mapping methods as a criterion to evaluate the adequacy of a surficial map which depicts floodplain Holocene alluvium.

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[80] ADWR Notice of Recently Published Soil Survey Maps, app. A (NRCS Soil Survey Report 2).
[81] 198 Ariz. at 342, 9 P.3d at 1081. Such information would include the comments submitted by the Arizona Geological Survey to ADWR, which ADWR filed with the Court on June 17, 2002.

Recommendation 9: The Court should direct ADWR to obtain the largest scale version of a map whenever possible.

Recommendation 10: The Court should direct ADWR to take special care in transferring or re-projecting any depiction on a surficial map to a base map.

D. Should ADWR consider the criteria specified in *Gila IV* to identify the subflow zone or have the criteria already been taken into account in the Arizona Supreme Court's holding that the saturated floodplain Holocene alluvium is the subflow zone?

This question was briefed prior to the hearing. On September 8, 2003, a ruling was issued subject to modification after considering the evidence presented during the hearing. The proposed ruling is adopted as the evidence is not sufficient to modify it.

In *Gila II*, the Supreme Court held that in order to determine "[w]hether a well is pumping subflow…comparison of such characteristics as elevation, gradient, and perhaps chemical makeup can be made. Flow direction can be an indicator."[82] After remand, the trial court found that if elevation, gradient, chemical composition, and flow direction are added to the concept that the subflow zone can be differentiated from adjacent tributary aquifers and the basin fill aquifer that contribute or receive discharge from the subflow zone, "a set of principles can be developed to define 'subflow.'"[83] The trial court found that combining the four factors with this concept was "[t]he only logical and rational way" to make *Southwest Cotton* and *Gila II* "consistent with the scientific principles" presented by the expert witnesses.[84]

Before discussing the "different sides or proposals" presented to the trial court, Judge Goodfarb found that *Gila II* and the uncontested evidence he had heard required that the subflow zone "be defined by at least the following principles:"

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[82] 175 Ariz. at 392, 857 P.2d at 1246.
[83] Goodfarb Order 34.
[84] *Id*.

> 1. The "subflow" zone must be adjacent and beneath a perennial or intermittent stream.
>
> 2. It may not be adjacent or beneath an ephemeral stream. However, it may be adjacent or beneath an ephemeral section of a perennial or intermittent stream, if the ephemeral section is caused by adjacent surface water diversion or groundwater pumping. There must, however, be a saturated zone beneath connected to similar zones beneath the upper and lower perennial or intermittent stream sections.
>
> 3. Except as set forth in paragraph 2 above, there must be a hydraulic connection between the surface stream and the "subflow" zone.
>
> 4. The "subflow" zone must be distinguished from adjacent tributary aquifers or connecting basin fill.
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> 5. The parameters of the "subflow" zone, if it is to be defined by reference to the saturated floodplain alluvium, Holocene alluvium, or younger alluvium, must be outside of and not include those tributary alluvial deposits known as "inliers" as indicated in [a figure in an expert's report]. (Numbers 6 and 7 are omitted because they are not germane to this discussion).[85]

The trial court then took up the different proposals for defining the subflow zone and concluded:

> After consideration of flow direction, water level elevation, the gradation of water levels over a stream reach, the chemical composition if available, and lack of hydraulic pressure from tributary aquifer and basin fill recharge which is perpendicular to stream and "subflow" direction, the Court finds the most accurate of all the markers is the edge of the saturated floodplain Holocene alluvium.[86]

The court gave the reasons for this determination. First, the floodplain Holocene alluvium "is the only stable geologic unit which is beneath and adjacent to most rivers and streams...."[87] Second, when the floodplain Holocene alluvium is saturated, "that part of the unit qualifies as the 'subflow' zone, where the water which makes up the saturation flows substantially in the same direction as the stream, and the effect of any side discharge from tributary aquifers and basin fill is overcome or is

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[85] *Id*. at 35-36.
[86] *Id*. at 56; *see also* 198 Ariz. at 337, 9 P.3d at 1076.
[87] Goodfarb Order 56.

negligible."[88] The subflow zone must be saturated because there must be a hydraulic connection between the stream and the subflow.

In further support of the determination that the subflow zone is the saturated floodplain Holocene alluvium, the trial court stated:

> If we add the following additional criteria, then even more certainty and reliability is provided. First, the water level elevation of the "subflow" zone must be relatively the same as the stream flow's elevation. Second, the gradient of these elevations for any reach must be comparable with that of the levels of the stream flow. Third, there must be no significant difference in chemical composition that cannot be explained by some local pollution source which has a limited effect. Fourth, where there are connecting tributary aquifers or floodplain alluvium of ephemeral streams, the boundary of the "subflow" zone must be at least 200 feet inside of that connecting zone so that the hydrostatic pressure effect of the side recharge of this tributary aquifer is negligible and the dominant direction of flow is the stream direction. Fifth, where there is a basin-fill connection between saturated zones of the floodplain Holocene alluvium and a saturated zone of basin fill, the boundary of the "subflow" zone must be 100 feet inside of the connecting zone so that the hydrostatic pressure effect of the basin-fill's side discharge is overcome and the predominant direction of flow of all of the "subflow" zone is the same as the stream's directional flow.[89] (Underlining in original.)

The Supreme Court held that "the [trial] court based its ruling on evaluation of the pertinent factors set forth in *Gila River II* for delineating the subflow zone."[90] The Court, foreshadowing similar arguments made in this proceeding, held:

> At oral argument, the groundwater users questioned…what role, if any, the criteria that we set forth in *Gila River II* and that the trial court used will play in determining subflow in different locations. The criteria that the trial court articulated were elaborations of, but consistent with, the more general criteria set forth in *Gila River II.* The trial court properly applied these criteria to the San Pedro River basin in order to determine the most appropriate subflow zone, and the weight of the evidence supports the trial court's identification of that zone as the "saturated" floodplain Holocene alluvium.[91]

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[88] *Id*. at 57.
[89] *Id*. at 57-58; *see* 198 Ariz. at 337-8, 9 P.3d at 1076-7.
[90] 198 Ariz. at 337, 9 P.3d at 1076.
[91] 198 Ariz. at 341-2, 9 P.3d at 1080-1.

The trial court considered each of the criteria specified in *Gila II*, and determined they are met within the saturated floodplain Holocene alluvium. The trial court did not simply identify or formulate a set of more specific criteria or parameters to delineate the subflow zone. The Supreme Court affirmed this order in all respects.

The Special Master finds that the criteria specified in *Gila IV* to delineate the subflow zone have already been taken into account in the Supreme Court's holding that the saturated floodplain Holocene alluvium is the subflow zone.

This determination means that ADWR is required to apply the same criteria when it cannot delineate the subflow zone utilizing the procedures approved by the trial court. ADWR may find stream segments where the procedures approved by the trial court are insufficient to delineate the subflow zone with the requisite accuracy and reliability. In those situations, *Gila IV* directs that ADWR must consider "insofar as they apply and are measurable," the "detailed criteria set forth in the trial court's order," and may consider "other criteria that are geologically and hydrologically appropriate for the particular location."[92] ADWR should report the reasons for selecting any other criteria it found appropriate for the location.

Recommendation 11: The Court should adopt the finding that the criteria specified in *Gila IV* to delineate the subflow zone have been taken into account in the Supreme Court's holding that the saturated floodplain Holocene alluvium is the subflow zone.

Recommendation 12: The Court should direct ADWR to use the criteria specified in *Gila IV* and any other criteria that are geologically and hydrologically appropriate for the particular location to delineate the subflow zone, if ADWR is unable to do so with the requisite accuracy and reliability

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[92] 198 Ariz. at 342, 9 P.3d at 1081.

utilizing the procedures approved by the Court. ADWR should report the reasons for selecting any other criteria it found appropriate for the location.

E. Should ADWR's subflow analysis consider predevelopment or current stream flow conditions?

This question was briefed prior to the hearing. On September 8, 2003, a proposed ruling was issued subject to modification after considering the evidence presented at the hearing. The ruling is modified based on subsequent evidence and arguments.

Parties argue that Judge Goodfarb, the Arizona Supreme Court, and Judge Ballinger have decided this issue. One party argues Judge Ballinger decided the issue in his January 22, 2002, order directing ADWR to prepare a report that:

> shall include…a method for including both perennial and intermittent streams as part of the subflow analysis, including streams that historically contained perennial or intermittent flows, but which now are ephemeral due to development and other human initiated actions. The Court…expects the department to formulate a proposal using readily available historical data that will permit determination of water levels and locations as of date(s) prior to widespread diversion and depletion of Arizona's stream flows.[93]

Judge Ballinger's directions to ADWR to present a "method" and "formulate a proposal" to delineate the lateral limits of the subflow zone in the San Pedro River Watershed do not constitute a ruling on this issue. Even considered in its entirety, the January 22, 2002, order cannot be interpreted to say that the trial court ruled predevelopment conditions should be used for the subflow analysis. The trial court gave directions to ADWR as to what the department was to present in its recommendations. The trial court did not decide this issue in that order.

In the proposed ruling, the Special Master stated that a close reading of the trial court's orders, *Gila II*, and *Gila IV* does not show this issue was presented to the trial court or to the Arizona Supreme Court or "that it was decided by either court with definiteness and clarity, that it can be said

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[93] Ballinger Order 1-2.

the law of the case was set."[94] The parties arguing that the issue of predevelopment vs. current conditions was presented to the trial court and to the Supreme Court, and both courts decided the issue, point to what has been called the "ephemeral stream exclusion" or "exception" and to the trial court's definition of an intermittent stream. The Special Master believes exception fits better than exclusion.

The Ephemeral Stream Exception

The exception is set forth in the second principle Judge Goodfarb found was necessary to define the subflow zone:

> [The subflow zone] may not be adjacent or beneath an ephemeral stream. However, it may be adjacent or beneath an ephemeral section of a perennial or intermittent stream, if the ephemeral section is caused by adjacent surface water diversion or groundwater pumping. There must, however, be a saturated zone beneath connected to similar zones beneath the upper and lower perennial or intermittent stream sections.[95]

The Cities argue that ADWR and they presented expert reports and testimony to the trial court, during the 1987 and 1994 hearings, indicating that in some river segments the groundwater/surface water connection had ceased to exist or had been severed due to development of water resources, and therefore, wells within these ephemeral reaches should be excluded from the adjudication. Furthermore, it is implicit in the ephemeral stream exception that current conditions must be used for the subflow analysis because the exception applies "if the ephemeral section is caused by adjacent surface water diversion or groundwater pumping," and these activities did not occur in predevelopment times. According to the Cities, the exception requires, at a minimum, determination of its applicability, and at a maximum, delineation of the subflow zone using current, not predevelopment, stream flow conditions. Because the Supreme Court affirmed the trial court's

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[94] Special Master's Order Determining Issues 1 Through 4, 3.
[95] Goodfarb Order 35.

order in its entirety including the principles, it is argued the law of the case was set, and the point of law is binding on the trial court under the doctrine of *stare decisis*.[96]

In his 66-page ruling with 36 pages of exhibits, Judge Goodfarb did not amplify or explain the exception, and he did not repeat it in the summary of his findings. The order does not shed light on the reasons for the exception.

The Cities presented copies of pages of some of the briefs they and the Nature Conservancy filed in the Arizona Supreme Court related to the *Gila II* and *Gila IV* appeals.[97] The Nature Conservancy's *Gila II* opening brief (May 15, 1992) stated in pertinent part:

> It would be a difficult task at best for the trial court to attempt now to reconstruct what happened to surface water appropriations as a result of subflow withdrawals throughout the Gila River System. Put another way, practicalities make it difficult to apply the proper test for "subflow" back to the point of restoring streams long ago depleted without formal objection registered (or litigation brought) by those who had prior appropriations in those streams. Instead, the most practical approach may simply be to exclude from the adjudication those wells in areas where the surface streams have already been completely, essentially permanently, depleted. Such areas would include, for example, the Santa Cruz River near Tucson, the lower Salt, and the lower Gila Rivers.[98]

The Cities' briefs filed in the Arizona Supreme Court in *Gila II* (May 15, 1992) and *Gila IV* (May 15, 1995) discussed the lack of hydraulic connection in ephemeral streams as a result of surface water diversions and groundwater pumping. The pages of the *Gila II* opening brief described the severing of hydraulic connection in the Lower Salt River due to the construction of dams, urbanization, and groundwater pumping. The pages from the *Gila IV* brief described how ephemeral streams can be caused by the severing of hydraulic connection as a result of human activity, and

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[96] The doctrine embodies the "principle that a decision made in one case will be followed in the next." A. SCALIA, A MATTER OF INTERPRETATION: FEDERAL COURTS AND THE LAW 7 (1997).

[97] Cities' Subflow Post-Hearing Opening Brief, exs. 9, 10, 11 (Mar. 3, 2004). SRP's objections to these exhibits were denied, but consideration of exhibits 10 (May 15, 1992, brief) and 11 (May 15, 1995, brief) was limited to the Cities' assertion that the issue of applying current, not predevelopment, stream conditions to the ephemeral stream exception was presented to the Arizona Supreme Court.

[98] *Id*. ex. 9 at 57-58.

argued that because there is no hydraulic connection between the stream and a groundwater aquifer, wells pumping within these ephemeral reaches do not impact subflow or stream flow.

The Supreme Court did not discuss the ephemeral stream exception in *Gila IV*. The word "predevelopment" appears only once in that opinion, in footnote 4 referring to the Nature Conservancy's proposal to define the subflow zone by the geographic area phreatophytes had occupied in predevelopment times. "Current" also appears once in footnote 5 used as a noun.

Next the Cities claim that the trial court's definition of an intermittent stream (adopted from ADWR's Technical Assessment as stated on page 25 of this report) shows the court ruled subflow analysis must use current conditions. The pertinent portion of the definition states that intermittent streams may have periods of reduced groundwater discharge as a result of "natural and cultural losses" or "uses."[99] The Special Master finds that the trial court adopted a commonly accepted definition of an intermittent stream.

The Special Master has carefully reviewed the papers, reports, and exhibits and has spent much time on this issue. The conclusion is that the Cities, the Nature Conservancy, and ADWR discussed before the trial court and, except ADWR, before the Arizona Supreme Court the requirement of hydraulic connection between the surface stream and the groundwater aquifer to define the subflow zone and the lack of hydraulic connection in certain streams, for example, the Lower Salt River and the Santa Cruz River near Tucson, as a result of surface water diversions and groundwater pumping. The Cities asserted their position that hydraulic connection between the surface water and the groundwater aquifer in the Lower Salt River has been altered as a result of

[99] Goodfarb Order 24.

human activities, and therefore, wells within the ephemeral reaches of the Lower Salt River are not withdrawing subflow.[100]

The Special Master concedes the Cities have argued, and well, this position not only before the trial court but also before the Supreme Court and the Special Master.[101] The Special Master cannot find, however, that the trial court ruled, and was affirmed by the Supreme Court, that subflow analysis must consider current and not predevelopment stream flow conditions, entitling the affirmed ruling to *stare decisis*. Judge Goodfarb's order shows he was deliberate with words and analysis, respectful of the needs for explanations of "reviewing appellate courts," and cognizant of the trial court's "duty to provide as much detail as it can to explain the factual decisions made."[102] The trial court did not explain the exception, and *Gila IV* provides no assistance with the search for an answer. The Special Master cannot conclude that the unexplained exception decided this issue as a principle, precedent, or point of law in this adjudication.[103] Neither the trial court nor *Gila IV* has decided whether ADWR's subflow analysis should consider predevelopment or current conditions.

The Special Master believes that in order to give effect to the plain language of the exception, and incorporate it into the subflow analysis, the applicability of the exception must be determined using post-development conditions. Under this view, a well will not be subject to the adjudication, if it meets all of the following conditions:

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[100] The condition described in the Lower Salt River may not exist to the same degree in other watersheds. Mr. Briggs declared, "[i]n the Verde Valley this is not a significant issue as there are no major upstream dams, nor has there been major groundwater development and overdraft." Philip C. Briggs Rebuttal Decl. ¶ 11a (June 27, 2003).

[101] *See* Affidavit of Doug Toy, P.E. in Cities' Response to ADWR's Subflow Report ex. 2 (June 17, 2002).

[102] Goodfarb Order 64.

[103] *Francis v. Ariz. Dept. of Transp., Mot. Veh. Div.*, 192 Ariz. 269, 271, 963 P.2d 1092, 1094 (Ariz. App. 1998); *City of Bisbee v. Cochise Co.*, 52 Ariz. 1, 6, 78 P.2d 982, 984 (1938); *see State ex rel. La Prade v. Cox*, 43 Ariz. 174, 30 P.2d 825 (1934). An instructive decision on the law of the case doctrine is *State v. King*, 180 Ariz. 268, 278-9, 883 P.2d 1024, 1034-5 (1994), *cert. denied*, 516 U.S. 880 (1995). Arizona recognizes the law of the case doctrine as a rule of procedure not substance.

> 1. The well is located within an ephemeral section of a perennial or intermittent stream,
>
> 2. The ephemeral section of the perennial or intermittent stream is or was caused by adjacent surface water diversion or groundwater pumping and not by climate or watershed changes,[104] and
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> 3. There is no saturated zone beneath the ephemeral section that is connected to similar saturated zones beneath the upstream and downstream perennial or intermittent sections.

The Special Master recommends that ADWR investigate and tabulate all wells that are or may be subject to the ephemeral stream exception. In this manner, the exception is reconciled with using predevelopment conditions for the subflow analysis.

Predevelopment Conditions

The parties who favor using current stream flow conditions argue that information of predevelopment conditions is unavailable, inconsistent, unverifiable, and unreliable making subflow determinations uninformed guesswork that does not satisfy the clear and convincing evidentiary standard; predevelopment conditions cannot be recreated after decades of surface water diversions and groundwater pumping; and using predevelopment conditions will result in an expanded subflow zone at odds with the "narrow concept" of subflow long adhered to by the Arizona Supreme Court.[105]

Those in favor of predevelopment conditions argue that additional evidence is available in other sources such as historical reports and maps; using current conditions would unfairly advantage claimants who have been pumping subflow without water rights, with unquantified water rights, or without regard for prior vested surface water rights; and if current conditions are used, claimants at the end of ADWR's watershed investigations would gain an unfair position because their claims will be adjudicated years from now when the subflow zone may be depleted.

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[104] Mr. Michael J. Lacey discussed the exception in his rebuttal declaration and pointed out the distinction between human activity and natural changes. Michael J. Lacey Rebuttal Decl. 6 (June 27, 2003).

[105] 175 Ariz. at 391, 857 P.2d at 1245.

A standard that satisfies all of these objections is a chronological point of reference:

1. That can be applied consistently, although the specific time period may vary from watershed to watershed;

2. For which evidence is available to delineate the lateral extent of the subflow zone as accurately and reliably as possible; and

3. That overcomes unfair practicalities due to the slow progress of the adjudication.

Predevelopment conditions are a consistent chronological point of reference that meets these criteria. The discrete time period will not be the same for all watersheds, but predevelopment conditions are the most consistent and fairest reference point for subflow analysis.

The experts expressed different opinions about the quality and quantity of available evidence to evaluate predevelopment stream flow conditions. An example are the views about the USGS Atlas (which ADWR proposes to use) that shows the location of predevelopment perennial streams and predevelopment water level contours. Dr. Montgomery and Mr. Anderson expressed concerns about the quality of the sources of information used to compile the Atlas.[106] On the other hand, Mr. Briggs used the Atlas as a source of predevelopment groundwater elevations data.[107] Mr. Gookin recommended that additional sources be studied and professional historians retained to assist with this part of the investigations. Mr. Briggs declared, “I disagree that a predevelopment subflow zone cannot be delineated. There is ample scientific and [anecdotal] evidence available to use to delineate a predevelopment subflow zone in the Salt River Valley.”[108] The Special Master concludes that more and better evidence of predevelopment conditions can be obtained, and the effort to obtain it must be made.

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[106] Errol L. Montgomery and Thomas W. Anderson Decl. 11 (June 17, 2002).
[107] Philip C. Briggs Decl. ¶ 7i (June 17, 2002).
[108] Philip C. Briggs Rebuttal Decl. ¶ 11a(2) (June 27, 2003).

ADWR has not had an opportunity to obtain and review additional maps, reports, and documents suggested by the experts who submitted declarations; conduct field investigations; analyze drilling records; and run models. After ADWR submitted the Subflow Report, it found the NRCS soil survey maps which Mr. Burtell testified "would be very useful for our work in the adjudications."[109] ADWR should be directed and allowed to obtain more concrete and useful information. Moreover, if adopted by the trial court, many of this report's recommendations will improve the investigations. It is premature to conclude that ADWR cannot obtain reliable evidence of predevelopment stream flow conditions.

Using predevelopment conditions precludes claimants whose water use claims will be adjudicated in the later phases of ADWR's watershed investigations from gaining an unfair position. If current conditions are used, claimants at "the back of the line"[110] who are pumping subflow would benefit because they could continue to withdraw subflow, and years from now their wells could be found to be outside the subflow zone delineated under then current conditions. This concern is heightened when claimants who are pumping subflow or stream flows without an appropriative water right are considered. The slow progress of investigations and adjudication of water uses is a reality that must be weighed in this discussion.

The concern that using predevelopment conditions might result in more wells included in the adjudication than under current conditions is unmerited. The subflow zone will remain as narrow as the saturated floodplain Holocene alluvium.

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[109] Hrg. Tr. 15:25 (Oct. 21, 2003).

[110] SRP's Opening Brief on Legal Issues 4 (June 6, 2003). While SRP argues claimants would "race to" the back of the investigations line, the fact is that at the pace this adjudication has been proceeding due to a variety of factors, there is not much immediacy for claimants outside of the San Pedro River Watershed "to race."

The time period selected to define predevelopment conditions will influence the accuracy and reliability of subflow determinations. Parties have suggested various years or periods to define predevelopment conditions:

> 1. 1848, the year the United States and Mexico signed the Treaty of Guadalupe Hidalgo (on February 2, 1848).
>
> 2. Post-1865 (after the Civil War).
>
> 3. Prior to about 1900 for surface water in highly developed watersheds.
>
> 4. 1931, the year *Southwest Cotton* was decided.
>
> 5. Prior to about 1940 for groundwater in highly developed watersheds.
>
> 6. February 17, 1978, the date Phelps Dodge filed a petition with the Arizona State Land Department to adjudicate water rights in portions of the Lower Gila River Watershed and the Upper Gila River Watershed including the San Francisco River, Chase Creek, and Eagle Creek.[111]

Selection of a date or period must consider the feasibility of obtaining the requisite technical data and evidence; potential delay and expense of those efforts and of subsequent investigations; level of accuracy and reliability of the subflow analysis; confidence of meeting the clear and convincing evidentiary standard; and fairness.

In its January 22, 2002, order, the trial court provided an appropriate time frame for defining predevelopment conditions that satisfies these concerns, namely, "prior to widespread diversion and depletion of Arizona's stream flows."[112] The word "widespread" is defined as "widely

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[111] On April 19, 1978, Phelps Dodge supplemented this petition to include additional lands in the Lower Gila River and Upper Gila River Watersheds. In 1979, the petitions were transferred to the Arizona Superior Court. 1979 Ariz. Sess. Laws, ch. 139, § 39 (effective Apr. 17, 1979).

[112] Ballinger Order 2.

extended…occurring over a wide area or extent."[113] The term indicates greater than minimal, localized, or sporadic diversion and depletion of stream flows as a result of human activity.

The evidence is not sufficient to select one of the dates or periods advocated by the parties. The Special Master believes the evidence together with the factors listed above favor selecting a date or period after 1865 and before 1940. The Special Master recommends that the discrete time period be an approximate chronological year or a range of years immediately prior to widespread diversion and depletion of a stream's flows as a result of human activity. The chronological year or range of years will not be the same for all watersheds.

Recommendation 13: The Court should direct ADWR to use predevelopment stream flow conditions for subflow analysis.

Recommendation 14: The Court should direct ADWR to investigate and tabulate all wells subject to the ephemeral stream exception set forth in the trial court's June 30, 1994, order.

Recommendation 15: The Court should define predevelopment stream flow conditions, for the purpose of subflow analysis, to mean a chronological year or a range of years immediately prior to widespread diversion and depletion of the stream's flows as a result of human activity.

F. Does ADWR's recommendation that the entire lateral extent of the floodplain Holocene alluvium be assumed to be saturated comport with *Gila IV*?

ADWR recommends "that the entire lateral extent of the floodplain Holocene alluvium be assumed to be saturated for the purpose of delineating the jurisdictional subflow zone."[114] The recommendation is based on the limitations of available data, variability of saturation of the

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[113] WEBSTER'S NEW WORLD DICTIONARY OF AMERICAN ENGLISH 1526 (3d ed. 1988); *cf*. A.R.S. § 1-213 relating to statutory construction ("Words and phrases shall be construed according to the common and approved use of the language.").
[114] Subflow Report 13.

floodplain Holocene alluvium, and the trial court's request to consider predevelopment stream flow conditions. ADWR explains:

> Determination of the saturated portion of the floodplain Holocene alluvium requires data on two subsurface conditions:
>
> - The thickness of the floodplain Holocene alluvium; and
> - The depth to the water table beneath the floodplain.
>
> …
>
> However, the two conditions indicated above cannot be determined with reasonable means in the San Pedro River watershed or elsewhere in the Gila River adjudication area. The thickness of the floodplain Holocene alluvium and the depth to the water table beneath the floodplain are highly variable, both spatially and temporally, and this makes the determination of saturation difficult. In many areas of the Gila River adjudication, detailed subsurface data for the floodplain simply do not exist or are limited, and additional data would have to be collected and analyzed at considerable cost and time. In the few areas where extensive subsurface data have been collected, it is often still difficult to define variations in the thickness of the Holocene alluvium across the floodplain and changes in the elevation of the water table over time.[115]

Concerning the thickness of the floodplain Holocene alluvium, ADWR gives an example of a "very costly" USGS hydrogeologic project in the Sierra Vista Subwatershed. Although the USGS used "very sophisticated and expensive geophysical and lithological data, the actual thickness of the Holocene alluvium could not be determined with any degree of certainty."[116] In "the remainder of the San Pedro River watershed and most of the Gila River adjudication area, well driller's logs will likely be the only source, if any, of subsurface geologic data for the floodplain," and "[t]he accuracy of this data is questionable."[117] "This lack of reliable data prevents the thickness of the floodplain Holocene alluvium from being determined with any certainty."[118]

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[115] *Id*.
[116] *Id*. at 14.
[117] *Id*.
[118] *Id*. at 15.

Regarding the water table beneath the floodplain, ADWR states there "is a lack of reliable data concerning the depth to the water table," which "is further exacerbated by the dynamic nature of the floodplain aquifer system," as "the water table sometimes chang[es] rapidly in response to storm runoff events and evapotranspiration by plants, and sometimes chang[es] slowly due to the effects of droughts and wet periods, seasonal differences, and pumping."[119] These "variations are not unique to recent times, but apparently also occurred during predevelopment conditions."[120]

Saturation or how much water is stored in the floodplain Holocene alluvium can vary. Dr. Matlock defined the terms as follows:

> "Saturated alluvium would be alluvium of which the pores are completely filled with water. Unsaturated would be a condition in which they're not completely filled with water."[121]

Mr. Burtell testified, "[t]here are times when it will be saturated and there are times when it's possible that it will not be saturated."[122] Mr. Harmon testified that the saturated extent of the floodplain Holocene alluvium "can change from year to year. It can change within a season with all types of recharge, inputs, discharge, different inflows and outflows….can change maybe from day to day….perhaps [from hour to hour] if you have a lot of wells turning on and off."[123] Saturation is dynamic.

ADWR believes its proposal is consistent with using predevelopment stream flow conditions for subflow analysis because "[b]y definition, floodplain Holocene alluvium was saturated at some point in predevelopment time."[124] The floodplain Holocene alluvium consists of sediments deposited under flood flow conditions. It, therefore, was saturated at the time floods deposited the sediments,

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[119] *Id*.
[120] *Id*.
[121] Hrg. Tr. 211:6-8 (Oct. 21, 2003).
[122] *Id*. at 43:9-11.
[123] *Id*. at 359:18-25 (Oct. 22, 2003).
[124] Subflow Report 17.

but for how long thereafter and to what extent the saturation lasted is debated. Mr. Ford declared that "the only processes that reduce the lateral extent of saturation from the historic maximum limit are human activity and climate cycles."[125] On the other side, Mr. Lacey testified, "[i]t would not have been saturated once the flood flows had receded."[126]

Mr. Page declared that ADWR's recommendation "is reasonable based on available water level data that suggests the depth to water in the floodplain Holocene alluvium is very shallow, indicating only a thin margin along the edges of this unit may be unsaturated…. [O]nly a thin upper portion of the floodplain Holocene alluvium is unsaturated.…"[127]

Resolving this issue is not easy. It would be wasteful to direct ADWR to do something that is not feasible, but it would be foolish to sidestep the law in a rush to expediency. The issue is whether the recommendation comports with *Gila IV*. The Special Master finds it does not.

The Clear and Convincing Evidentiary Standard

After reviewing the trial court's order which had sought "to determine the most appropriate subflow zone," the Supreme Court affirmed the order holding that "the weight of the evidence supports the trial court's identification of that zone as the 'saturated' floodplain Holocene alluvium."[128] *Gila II* and *Gila IV* emphasize that the test to delineate the lateral extent of the subflow zone must not be "defective" or "flawed." *Gila II* admonishes that using a defective test "would adversely affect the adjudication" because "errors in every HSR" would have to be litigated, exacerbating "an already lengthy and costly process," and a flawed test "could cause significant

[125] Jon R. Ford Decl. ¶ 14c (June 17, 2002).
[126] Hrg. Tr. 417:7-8 (Oct. 22, 2003).
[127] Oliver S. Page, Peter M. Pyle, and Jean M. Moran Decl. 16 (June 17, 2002).
[128] 198 Ariz. at 342, 9 P.3d at 1081.

injustice."[129] *Gila IV* is more direct - "it is critical that any test used for determining the boundaries of a subflow zone be as accurate and reliable as possible."[130]

The test must be so robust because one "who asserts that underground water is a part of a stream's subflow must prove that fact by clear and convincing evidence."[131] Only clear and convincing evidence will rebut the presumption that underground waters are percolating, and are therefore, not appropriable as subflow. If ADWR uses the proper test to delineate the lateral extent of the subflow zone, "its determination that a well is pumping appropriable subflow constitutes clear and convincing evidence."[132]

Parties have argued throughout this proceeding that ADWR's proposed procedures, in whole or in part, do not satisfy the clear and convincing evidentiary standard associated with the presumption that underground waters are percolating and are not appropriable as subflow. Of all the issues litigated, this is the only one that, in the Special Master's opinion, requires that its resolution closely review the clear and convincing standard.

In Arizona, a party who has a burden of proof by clear and convincing evidence must show that the claim is "highly probable."[133] In the adjudication, when ADWR reports a well is pumping appropriable subflow, the report is considered to be a determination that it is highly probable the well is pumping appropriable subflow from the saturated floodplain Holocene alluvium. The standard "is more exacting than the standard of more probably true than not true but is less exacting than the

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[129] 175 Ariz. at 388, 857 P.2d at 1242.
[130] 198 Ariz. at 335, 9 P.3d at 1074.
[131] *Id*.; *see also* 39 Ariz. at 85, 4 P.2d at 376 (*Southwest Cotton)*.
[132] 175 Ariz. at 392, 857 P.2d at 1246.
[133] *State v. Renforth*, 155 Ariz. 385, 388, 746 P.2d 1315, 1318 (Ariz. App. 1987); *State v. King*, 158 Ariz. 419, 763 P.2d 239 (1988); Recommended Arizona Jury Instructions (Civil) 3d Standard 10 ("A party who has the burden of proof by clear and convincing evidence must persuade you by the evidence that the claim is highly probable….") ("RAJI Civil Standard 10").

standard of proof beyond a reasonable doubt."[134] Under *Renforth* and *King*, the highly probable standard does not require that ADWR's determination be either certain or unambiguous.

The Special Master finds that the recommended assumption will not satisfy the clear and convincing standard. The assumption is expedient and likely less costly to implement than alternatives. The evidence, however, shows saturation fluctuates even in predevelopment conditions, and a thin upper portion of the floodplain Holocene alluvium is unsaturated.

To include a well in the adjudication, it is not enough to determine it is highly probable the entire lateral extent of the floodplain Holocene alluvium was saturated at some point. It must be shown it is highly probable the well is pumping subflow from the saturated floodplain Holocene alluvium. If the well owner disputes this assessment, the owner has the burden of proving by a preponderance of the evidence that the well is outside the subflow zone or is not withdrawing subflow.

Valid technical efforts must be undertaken to determine the saturated portion of the floodplain Holocene alluvium. The department avows it "has very limited resources available" to fund ongoing hydrogeologic projects or to obtain data.[135] Mr. Burtell described projects ADWR is undertaking or funding to collect more data in the San Pedro River Watershed and testified, "there is a tremendous amount of information that continues to be collected for that area."[136] Mr. Briggs declared "ADWR's proposed approach to delineation of the subflow zone to be far too conservative, pleading lack of data. While these data may not currently exist for every mile of Holocene alluvium, the data exist where there are wells (and hence a need to know). Where these data exist, they should

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[134] RAJI Civil Standard 10.
[135] Subflow Report 14.
[136] Hrg. Tr. 54:23-25 (Oct. 21, 2003). "The Sierra Vista subwatershed has been, and continues to be, one of the most studied areas in Arizona by geologists and hydrologists." Subflow Report 13.

be used."[137] ADWR may not have at this point sufficient information with the desirable level of detail, but it is striving to remedy this situation. This campaign must continue, and if necessary intensified. The task will not be simple, but the Special Master believes, after considering all the evidence, that the saturated portion of the floodplain Holocene alluvium can be established by clear and convincing evidence.

Recommendation 16: The Court should not adopt the recommendation that the entire lateral extent of the floodplain Holocene alluvium be assumed to be saturated for the purpose of delineating the subflow zone.

Recommendation 17: The Court should direct ADWR to determine the saturated portion of the floodplain Holocene alluvium as accurately and reliably as possible.

G. Are ADWR's recommendations sufficient to identify and exclude tributary aquifers, basin fill saturated zones, and ephemeral streams?

The subflow zone must "be differentiated from adjacent geologic units such as tributary aquifers and the basin-fill aquifer which discharge into it or receive discharge from it…."[138] The trial court found this concept is necessary to define subflow consistent with *Southwest Cotton*, *Gila II*, and the scientific evidence the court had heard.

Subflow must be part of the surrounding floodplain of a stream but cannot be part of the alluvial plains of either a tributary aquifer (even if there is an alluvial connection between the tributary aquifer and the floodplain Holocene alluvium of the stream) or of an ephemeral stream. The trial court ruled:

> Those parts of the alluvial plain which [subflow] may be a part of or which it is connected to must be the alluvial plain of a perennial or intermittent stream and <u>not</u> an ephemeral stream or a part of the alluvial plain of a tributary aquifer even if there is an alluvial connection. Where the alluvial plain of tributary aquifers or ephemeral

[137] Philip C. Briggs Decl. ¶ 7g (June 17, 2002).
[138] Goodfarb Order 34.

> streams connects to the floodplain Holocene alluvium of the stream itself and provides tributary or basin fill recharge, that tributary aquifer must also be excluded because its flow direction is different and often perpendicular to the stream-flow direction.[139] (Emphasis in order.)

The trial court added these two criteria so that "more certainty and reliability" would be provided to the definition of subflow:

> Fourth, where there are connecting tributary aquifers or floodplain alluvium of ephemeral streams, the boundary of the "subflow" zone must be at least 200 feet inside of that connecting zone so that the hydrostatic pressure effect of the side recharge of this tributary aquifer is negligible and the dominant direction of flow is the stream direction. Fifth, where there is a basin-fill connection between saturated zones of the floodplain Holocene alluvium and a saturated zone of basin fill, the boundary of the "subflow" zone must be 100 feet inside of the connecting zone so that the hydrostatic pressure effect of the basin-fill's side discharge is overcome and the predominant direction of flow of all of the "subflow" zone is the same as the stream's directional flow.[140] (Underlining in order.)

Flow direction in the subflow zone must not be significantly affected by the pressure of side discharge from adjacent tributary aquifers or the basin fill aquifer. The water in the subflow zone must flow "substantially in the same direction as the stream, and the effect of any side discharge from tributary aquifers and basin fill is overcome or is negligible."[141] The 100-foot and 200-foot setbacks overcome or substantially reduce the effects of side discharge. *Gila IV* affirmed these rulings.

ADWR does not explicitly recommend procedures to exclude tributary aquifers, areas of basin fill recharge, and the alluvial plains of ephemeral streams. A group of parties argues that ADWR should be directed to propose procedures that take into account these exclusions from the subflow analysis.

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[139] *Id*. at 57.
[140] *Id*. at 57-58.
[141] *Id*. at 57.

The Subflow Report sets forth ADWR's proposed procedures to identify perennial, intermittent, and effluent-fed streams and delineate the lateral extent and saturated portion of the floodplain Holocene alluvium.[142] Because methodologies to locate tributary aquifers, areas of basin fill recharge, and ephemeral streams are not proposed, and ADWR's recommendations relate to the floodplain Holocene alluvium of a stream and its saturated portion, it can reasonably be concluded that ADWR will exclude tributary aquifers, areas of basin fill recharge, and ephemeral streams from the subflow analysis. The Special Master believes ADWR understands the exclusions described in the trial court's order and affirmed in *Gila IV*, but for certainty recommends that ADWR exclude from the subflow zone connecting tributary aquifers, areas of basin fill recharge, and the alluvial plains of ephemeral streams.

Recommendation 18: The Court should direct ADWR to exclude tributary aquifers, areas of basin fill recharge, and the alluvial plains of ephemeral streams from the subflow zone.

Recommendation 19: The Court should adopt Chapter 2 of the Subflow Report to the extent it does not conflict with any other recommendation made in this report.

III. CONE OF DEPRESSION (Chapter 3 of the Subflow Report)

A. Does ADWR's recommended drawdown of greater than or equal to 0.1 foot, where the cone of depression has reached the edge of the subflow zone, comport with *Gila IV*?

ADWR proposes to include a well in the adjudication if, at the time of the modeling, two conditions are met. The "first condition is that the simulated cone of depression has reached the edge of the jurisdictional subflow zone and drawdown at that point is greater than or equal to 0.1 foot, an amount that can be accurately measured in the field using standard water level measuring

[142] Subflow Report 5.

equipment."[143] The second condition is discussed in the next section. The distance of 0.1 foot is 1 and 1/5 (or 1.2) inch.

Gila IV affirmed the trial court's order that wells located outside the lateral extent of the subflow zone "may be included in the adjudication if 'it is proven that their "cones of depression" [footnote omitted] reach the "subflow" zone and the drawdown from the well affects the volume of surface and "subflow" in such an appreciable amount that it is capable of measurement.'"[144] ADWR's recommendation addresses how to measure an appreciable amount.

Because it lacked pertinent evidence, the trial court did not establish a test for determining a well's cone of depression but ruled that "whatever test ADWR finds is realistically adaptable to the field and whatever method is the least expensive and delay-causing, yet provides a high degree of reliability, should be acceptable."[145] As *Gila IV* affirmed the trial court's order in its entirety, ADWR's recommendation will comport with *Gila IV* if it satisfies these criteria.

Computer modeling is generally accepted in the scientific community to measure water impacts.[146] Messrs. Briggs, Ford, Harmon, Lacey, Page, Marra, Dr. Mock, Dr. Montgomery, and ADWR have, and use, computer modeling in their professional work. These experts and ADWR have used analytical and numerical models for a variety of projects, and different models are used for different purposes, but the point is that professionals, including most of the experts who testified in this proceeding, use modeling as a tool to measure hydrologic impacts.

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[143] Subflow Report 31. "The cone of depression is the funnel-shaped area around a well where the withdrawal of groundwater through the well has lowered the water table." 198 Ariz. at 342-3 n.9, 9 P.3d at 1081-2 n.9; s*ee also* 175 Ariz. at 391 n.10, 857 P.2d at 1245 n.10.

[144] 198 Ariz. at 342-3, 9 P.3d at 1081-2.

[145] *Id*. at 343, 1082 (quoting Goodfarb Order 62).

[146] Hrg. Tr. 79:18-25 - 80:1:5 (Oct. 21, 2003); 315:8-11 (Oct. 22, 2003).

ADWR recommends using computer modeling to measure the impact of a well's cone of depression on the subflow zone. ADWR does not give reasons for selecting a 0.1 foot drawdown level, but Mr. Ford posited that:

> ADWR is proposing it because the Theis equation extends the cone of depression an infinite distance with an infinitesimally small drawdown. Thus, some practical drawdown cutoff is required. Using professional judgment, ADWR decided that the radius at 0.1 foot of drawdown represents the practical limit of the cone of depression.[147]

According to Mr. Ford, a well's cone of depression extends beyond the point where an impact of 0.1 foot is measured. ADWR has simply selected 0.1 foot to represent the limit of the cone of depression.

Reliability of Modeling a 0.1 Foot Drawdown

The principal objections against ADWR's proposal go to the reliability of modeling a 0.1 foot drawdown at the edge of the subflow zone. First, although a computer program, like the THWELLS model ADWR proposes to use, will simulate a 0.1 foot drawdown, this predicted or simulated drawdown will not match the actual drawdown measured in the field. Second, it is not possible to determine that a drawdown of 0.1 foot is due to a specific well's pumping because recharge, phreatophytes, pumping from other wells, surface water diversions, changes in river stage, and diurnal flow variations can cause aquifer drawdowns that cannot be isolated from the impact of a particular well. The objectors argue that this lack of reliability will not satisfy the clear and convincing evidentiary standard ADWR must meet to determine that a well's cone of depression has reached the subflow zone.

ADWR cautions that:

> It is important to remember that the accuracy of model simulations will in most, if not all, cases be far less accurate than the ability to measure drawdown in the field.

[147] Jon R. Ford Rebuttal Decl. ¶ 21 (June 27, 2003). ADWR proposes to use the THWELLS model, an analytical model described in chapter 3, section C, of this report, which is based on the Theis equation. The other model is a numerical model named MODFLOW also described in the same section.

Simulated water levels from even the most carefully calibrated MODFLOW models are typically no closer than ± 5 to 10 feet from the actual water levels measured in the field. And, unless water level data are available at the pumping well and at the edge of the jurisdictional subflow zone, it will be difficult to determine if the model simulations are overestimating or underestimating the true drawdown at these points.[148] (Emphasis added.)

The objectors focus on the underlined sentence to show the disparity between simulated and measured drawdowns even when using the most carefully calibrated MODFLOW model. It is not argued that field technicians cannot measure a drawdown of 0.1 foot in the field with standard hydrologic instruments. Although the trial court stated in 1994 that it "believes such close measurements [as a 0.1 foot drawdown] are difficult, at best, in the field,"[149] the testimony did not substantiate this belief. Mr. Mason testified that ADWR's technicians can measure in the field a well's drawdown to 0.1 foot, and in some cases, even down to 0.01 or .05 of a foot.[150] The objection is that a computer model's simulated drawdown will not match the field measured true drawdown.

The MODFLOW model divides an aquifer into rectangular blocks which are then organized by rows, columns, and layers. Each block is called a cell. MODFLOW can consider numerous cells. Mr. Ford declared that:

> [E]ach cell can have only a single value for each required parameter. The model assumes the water level in a given cell is everywhere the same. Therefore, if the cell size is such that the actual water level varies five to ten feet across the cell, the model cell value would vary from field values by the five to ten feet cited.[151]

A difference between a value representing a cell and a field measurement "does not imply error" but "means that the average value for the area represented by the cell size is different than at a point

[148] Subflow Report 31-32.
[149] Goodfarb Order 62.
[150] Hrg. Tr. 68:9-14 (Oct. 21, 2003). Dr. Montgomery testified, "[i]t's easy to measure a change in water level of a tenth of a foot if that change occurs over a short period." *Id*. at 120:6-7.
[151] Jon R. Ford Rebuttal Decl. ¶ 66 (June 27, 2003).

within the model cell."[152] Dr. Mock likewise opined, "I doubt that the 5-10 foot number is from the comparison of simulated to measured drawdowns, as opposed to the comparison of simulated to measured water-level elevations for a specific location."[153] A difference of five to ten feet in drawdown may not necessarily be found at every location within the cell or test area.

Mr. Ford expressed his opinion about the reliability of the MODFLOW model as follows:

> If MODFLOW could not be more accurate than plus or minus 10 feet in its ability to predict the head distribution or drawdown in an aquifer, it would be of little use. However, MODFLOW is widely used in both the environmental engineering and ground water supply communities to analyze extremely complex situations. Federal agencies…rely upon the ability and accuracy of MODFLOW. So do many state agencies that are concerned about ground water contamination and water rights administration.[154]

Dr. Montgomery and Mr. Anderson declared:

> While model projections have a high level of precision, they are not necessarily accurate. Model projections can only be as accurate as the hydraulic parameter values used for model input. Relatively small changes in input parameters may result in substantial changes in model projections for drawdown.[155]

Dr. Mock similarly declared about the importance of reliable parameter values:

> Theis and MODFLOW…models can accurately calculate drawdowns to the hundredth of a foot or better, given acceptable parameter inputs. The real concern should be for the parameters used in these models.[156]

According to Mr. Mason, a computer model's uncertainty arises from the many parameters the modeler is adjusting such as hydraulic conductivity, saturated thickness, and storage coefficient,

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[152] *Id*. at ¶ 51.
[153] Peter A. Mock Rebuttal Decl. 7 (June 27, 2003).
[154] Jon R. Ford Rebuttal Decl. ¶ 52 (June 27, 2003).
[155] Errol L. Montgomery and Thomas W. Anderson Rebuttal Decl. 17 (June 27, 2003).
[156] Peter A. Mock Rebuttal Decl. 7 (June 27, 2003). Messrs. Harmon and Palumbo declared, "Briggs recommends that well information [in ADWR's records] such as well depth, water levels, water quality, should be used in helping to determine whether any individual well should be subject to the Adjudication. We agree with this statement." Eric J. Harmon and Mark R. Palumbo Rebuttal Decl. 32 (June 27, 2003).

but once these are defined by calibration, Mr. Mason agreed that "drawdown can be fairly accurately predicted."[157]

Gila IV requires that the cone of depression test must yield results with a high degree of reliability. Under the clear and convincing evidentiary standard, ADWR's determination that a well's cone of depression impacts the subflow zone means it is highly probable the cone of depression has reached the edge of the subflow zone. The Special Master finds that a computer model's simulation of a greater than or equal to 0.1 foot drawdown can satisfy the degree of reliability required by *Gila IV* and the highly probable standard of clear and convincing evidence. The requisite reliability will depend, as Dr. Mock and Dr. Montgomery stated, on the quality and quantity of parameter inputs. A focused and reasonable effort to collect and use reliable data and information must be made if a high degree of reliability is to be attained.

Alternatives to a 0.1 Foot Drawdown

Dr. Montgomery and Messrs. Harmon, Palumbo, and Anderson suggested a drawdown of ten feet. This level is based on ADWR's well spacing and impact standards, for wells in active management areas, of ten feet of drawdown over the first five years of operations, to determine well-to-well impacts.[158] Dr. Montgomery also suggested five to ten feet based on the drawdown that can be reliably simulated with MODFLOW according to ADWR's statements in the Subflow Report.

Mr. Ford declared that:

> In the case of well-to-well interference, the usual issue is whether a new well would significantly reduce the yield of a nearby existing well. In that case, well yield is not particularly sensitive to (affected by) drawdown, so a 10-foot criterion may be appropriate. In the case of determining the radius of the cone of depression, a 10-foot criterion is not appropriate because…the radius of the cone of depression is very different if the drawdown criterion is different by only a small amount.[159]

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[157] Hrg. Tr. 72:18-21 (Oct. 21, 2003).
[158] Temporary Rule R12-15-830 (Well Spacing and Well Impact) (Mar. 11, 1983); *see* A.R.S. § 45-598(A).
[159] Jon R. Ford Rebuttal Decl. ¶ 69 (June 27, 2003).

According to Mr. Ford, ADWR's well spacing standards are not intended to determine if a well's cone of depression impacts the subflow zone, but to determine if a well will interfere with another well. The standards relate to a well's pumping lift. Measuring a well's potential interference with a nearby well is, however, not the same as measuring the impact of a cone of depression on the subflow zone in accordance with *Gila IV*.

Mr. Gookin testified that if a ten-foot drawdown standard were adopted, "[b]y the time this adjudication is done, it would destroy the stream."[160] Mr. Page declared that "if all wells were subject to this standard the San Pedro River would become an ephemeral stream."[161] This consequence is due to the fact that a well's cone of depression extends farther out than the point where a ten-foot drawdown is measured. A well will withdraw water from the subflow zone long before a ten-foot drawdown level is reached.

Mr. Gookin suggested a maximum drawdown of 0.25 foot, but only if 0.1 foot is found "to be too tight a measurement."[162] Because the Special Master does not find that 0.1 foot is too tight a measurement for a cone of depression test, a 0.25 foot drawdown is not considered.

Mr. Briggs recommended implementing a concept often used to investigate the feasibility of recovering contaminated groundwater called "capture zone." The capture zone is the area where pumping the well depresses water levels. "All groundwater within the capture zone ultimately reaches the pumped well," but "[a]ll groundwater outside the capture zone, even if within the 'cone of depression,' escapes the effect of the well and continues down gradient."[163] Mr. Briggs posited that "drawdown" is not the issue, but "capture" of water by a well is the trial court's concern.

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[160] Hrg. Tr. 315:23-24 (Oct. 22, 2003).
[161] Oliver S. Page Rebuttal Decl. 10 (June 27, 2003).
[162] T. Allen J. Gookin Rebuttal Decl. ch. XI, 2 (June 27, 2003); *see also* Peter A. Mock Rebuttal Decl. 8 (June 27, 2003).
[163] Philip C. Briggs Decl. ¶ 8a (June 17, 2002).

Messrs. Harmon and Palumbo found the concept "confusing in the context of this Adjudication," although it "does appear to be valid."[164] Mr. Ford declared that:

> Although capture analysis would demonstrate that a well is depleting the Subflow Zone, capture analysis is not by itself sufficient, because places likely exist where a pumping well located outside the Subflow Zone induces water to leave the Subflow Zone that is not captured by the well even though the Subflow Zone is still depleted. Furthermore, Mr. Briggs does not provide a method for performing the capture zone analysis. In my experience, some sort of drawdown analysis is first required in performing a capture zone analysis. Thus, Mr. Briggs' suggestion that ADWR perform capture zone analysis would require more effort, not less.[165]

Dr. Montgomery and Mr. Anderson opined that capture zone analysis considers the "presence or absence of a groundwater divide" rather than "drawdown at the edge of the subflow zone."[166] The issue of a groundwater divide in the cone of depression analysis is discussed in the next section. The Special Master finds that although capture zone analysis may be a method to measure the impact of a well on the subflow zone, there is insufficient evidence in the record to conclude that ADWR's recommended procedures should be rejected in favor of capture zone analysis.

Economy and Expediency

ADWR's proposed cone of depression test must also be evaluated alongside the alternatives in order to determine which is the least expensive and delay-causing method. Alternatives presented consisted of using monitoring wells rather than modeling, and second, adopting higher drawdown levels that allegedly can be simulated more accurately than 0.1 foot.

Dr. Montgomery and Mr. Anderson recommended that "monitor wells should be used to determine if, and or when, the hydraulic gradient is inclined downward from the subflow zone toward a pumping well."[167] To determine if the hydraulic gradient is continuously inclined

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[164] Eric J. Harmon and Mark R. Palumbo Rebuttal Decl. 33 (June 27, 2002).
[165] Jon R. Ford Rebuttal Decl. ¶ 27 (June 27, 2003).
[166] Errol L. Montgomery and Thomas W. Anderson Rebuttal Decl. 16 (June 27, 2003).
[167] *Id*. at 18.

downward from the subflow zone to a well, according to Dr. Montgomery, ADWR should drill monitor wells near the subflow zone and measure water levels in these and other wells. He estimated two monitor wells for each existing well would be appropriate to determine if the hydraulic gradient has reversed.[168] Dr. Montgomery could not estimate the number of wells that would have to be drilled and at what cost. As there are nearly 6,500 wells in the San Pedro River Watershed,[169] at least more than 6,500 monitor wells would have to be drilled. Mr. Marra testified that determining the cost of drilling and setting up a monitor well is "a difficult question to answer because monitor wells can be designed for different reasons and they can be designed at different depths and all of these factors will be involved in making an estimate of the cost," but he estimated the cost of drilling two wells to monitor a one thousand gallons per minute well with a depth to water of 300 feet "could range from $25,000 to $30,000."[170] A consideration for such a project is that landowners might deny access for drilling wells.

ADWR has stated it "does not currently have the resources to conduct cone of depression tests across wide areas of the Gila River adjudication" even using modeling.[171] During the past three years, ADWR has made the trial court, Special Master, and parties well aware of its weak budget situation. The Special Master finds that for reasons of cost, implementation, and delay such a well monitoring project is neither feasible nor practical and would not satisfy *Gila IV's* criteria of economy and expediency.

After considering the extensive evidence presented on this issue, the Special Master finds that computer modeling is an appropriate, workable, and reliable method to conduct cone of depression

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[168] Hrg. Tr. at 133:24 - 136:13; 154:20 - 155:2 (Oct. 21, 2003).
[169] Oliver S. Page, Peter M. Pyle, and Jean M. Moran Decl. 30, 32 (June 17, 2002). Dr. Mock characterized this alternative as "the largest hydrogeologic field investigation program in human history.…" Peter A. Mock Rebuttal Decl. 36 (June 27, 2003).
[170] Hrg. Tr. 443:3-12 (Oct. 22, 2003); *cf*. W. Gerald Matlock Rebuttal Decl. ¶ 11(m) (June 27, 2003).
[171] Subflow Report 22.

tests, and second, ADWR's recommended drawdown of greater than or equal to 0.1 foot drawdown comports with *Gila IV*. The modeling of a simulated drawdown of greater than or equal to 0.1 foot is realistically adaptable to the field, is the least expensive and delay-causing method, and provides a high degree of reliability. This finding is valid as long as ADWR strives to obtain reliable data and information to safeguard the requisite reliability of the cone of depression test. The cone of depression tests must not be allowed to become unreasonably theoretical exercises. There must be an ongoing reasonable effort to obtain and use reliable data for the model's parameters.

Recommendation 20: The Court should adopt ADWR's recommended drawdown of greater than or equal to 0.1 foot where a well's cone of depression has reached the edge of the subflow zone.

Recommendation 21: The Court should direct ADWR to obtain and use reliable data and information on an ongoing basis to safeguard the reliability of the cone of depression test.

B. Does ADWR's recommended condition that the water level in a well be below the water level in the subflow zone during pumping comport with *Gila IV*?

ADWR recommends that a well be included in the adjudication if at the time of modeling, "the water level in the well is *below* the water level in the jurisdictional subflow zone during pumping. If the water level in the well is *above* the water level in the jurisdictional subflow zone during pumping, the well cannot be pumping subflow."[172] (Italics in report.)

Messrs. Harmon and Palumbo declared that, "[i]n order for a well to withdraw appropriable subflow, the groundwater gradient must flow from the subflow zone to the well over the entire distance between the subflow zone and the well."[173] Dr. Montgomery and Mr. Anderson declared that ADWR "has <u>incorrectly</u> indicated that if the cone of depression reaches a stream, and if [the] pumping groundwater level at the well is lower than the stream, then the well is drawing

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[172] Subflow Report 31.
[173] Eric J. Harmon and Mark R. Palumbo Decl. 36, Figs. 1-3 (June 17, 2002).

groundwater from the stream" because "[e]ven if the cone of depression reaches the stream, water is not drawn from the stream and/or subflow, unless an inclination of hydraulic gradient is demonstrated to occur continuously across the distance from the stream to the pumping well."[174] (Underlining in declaration.) These experts submitted conceptual diagrams showing situations where the water level in a well is below the water level in the subflow zone, or a well's cone of depression has reached the subflow zone, but the well is not withdrawing subflow.

Messrs. Harmon, Palumbo, Anderson, and Dr. Montgomery believe ADWR must show that the hydraulic gradient between the well and the subflow zone has reversed. In other words, the gradient flows downward continuously from the subflow zone to the well rather than flowing from the well down to the stream. Another way of expressing this point is to say that the groundwater divide, "the point at which groundwater either goes to the well or to the river, has reached the subflow zone."[175] In short, whether a well's cone of depression depletes subflow or stream flow depends on the direction and magnitude of the hydraulic gradient between the stream and the well.

To determine if the hydraulic gradient is continuously inclined downward from the subflow zone to a well, according to Dr. Montgomery, ADWR should drill monitor wells near the subflow zone and measure water levels in these and other wells. Dr. Montgomery estimated two monitor wells for each existing well would be appropriate to determine if the hydraulic gradient has reversed.[176] Dr. Montgomery could not estimate the number of wells that would have to be drilled and at what cost. As there are nearly 6,500 wells in the San Pedro River Watershed,[177] at least more than 6,500 monitor wells would have to be drilled. This well monitoring project has been previously described, and the Special Master has found that for reasons of cost, implementation, and delay, such

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[174] Errol L. Montgomery and Thomas W. Anderson Decl. 20, Figs. 1-8 (June 17, 2002).
[175] Hrg. Tr. 116:14-16 (Oct. 21, 2003).
[176] *Id*. at 133:24 - 136:13; 154:20 - 155:2 (Oct. 21, 2003).
[177] Oliver S. Page, Peter M. Pyle, and Jean M. Moran Decl. 30, 32 (June 17, 2002).

a project is neither feasible nor practical and would not satisfy *Gila IV's* criteria of economy and expediency.

Mr. Ford disagrees with ADWR's second condition because pumping from a well whose cone of depression reaches the subflow zone, even if the hydraulic gradient has not been reversed, "will induce some amount of water to exit the subflow zone."[178] That amount of water will not enter a well whose water level is above that of the subflow zone, but will travel downstream generally parallel to the subflow zone. According to this view, because some appropriable water has been induced out of the subflow zone, even when the water does not flow toward the well whose cone of depression has entered the subflow zone, the well should be included in the adjudication. Dr. Montgomery and Mr. Anderson disagreed with Mr. Page's declaration that subflow leaves the subflow zone as soon as a well's cone of depression expands to the subflow zone.

Mr. Ford declared that adoption of ADWR's condition "would require DWR to measure the water levels in each individual well, which is problematic" because "[p]umping levels are somewhat difficult to measure, and they often vary seasonally and with irrigation return flows or other recharge," and "the construction of many wells makes it virtually impossible to measure their pumping levels."[179]

Mr. Mason, manager of ADWR's Groundwater Modeling Section, testified regarding ADWR's proposed cone of depression test. He testified that ADWR proposes "three criteria," the first two being the two previously stated conditions, and the third is that the groundwater divide has reached the subflow zone.[180]

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[178] Jon R. Ford Decl. ¶ 19b (June 17, 2002).
[179] *Id*. at ¶ 19c.
[180] Hrg. Tr. 116:10-16; 77:5-10 (Oct. 21, 2003).

Dr. Mock and Mr. Gookin did not find ADWR's second condition useful and suggested a way to make it less confusing. Dr. Mock declared that the condition "is acceptable" only "[a]s long as the level of the jurisdictional subflow zone up to its entrance into the basin of interest is considered."[181] It "is difficult to conceive of a well that won't meet this 'second condition'" because "all wells in a basin containing a subflow zone will have water levels below the stage of the river at the point where it enters the basin."[182] Mr. Toy declared that this concept ignores the existence of natural hydraulic boundaries "such as bedrock boundaries" that "can limit or prevent subflow from the head of a basin ever reaching certain basin areas," and secondly, natural, incidental, and artificial recharge (such as Central Arizona Project water and effluent).[183] Dr. Matlock declared the "concept ignores the fact that wells draw water from several other sources."[184]

The trial court found seven principles necessary to define the subflow zone (the first five are discussed in chapter 2, section D). The seventh principle, which covers this issue, is: "Wells located outside the lateral parameters of the defined 'subflow' zone are not included unless it is proven that their 'cones of depression' reach the 'subflow' zone and the drawdown from the well affects the volume of surface and 'subflow' in such an appreciable amount that it is capable of measurement."[185] This principle has two elements, first, the well's cone of depression has reached the subflow zone, and second, the well's drawdown affects subflow and stream flow in a measurable amount.

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[181] Peter A. Mock Decl. 26 (June 17, 2002).

[182] *Id*. at 27. Mr. Gookin shares this view declaring that "[a]ny well outside the subflow zone should be deemed to be taking subflow once the piezometric (water table) surface of that well drops below the water elevation of the river entering the individual valley in consideration." T. Allen J. Gookin Decl. sec. 3, 3 (June 17, 2002).

[183] Doug Toy Rebuttal Decl. 2, 3 (June 27, 2003).

[184] W. Gerald Matlock Rebuttal Decl. ¶ 15(l) (June 27, 2003).

[185] Goodfarb Order 36. In the summary of its findings, the trial court stated that in order to include in the adjudication a well located outside the subflow zone, there must be a finding that the well's cone of depression "has now extended to a point where it reaches an adjacent 'subflow' zone, and by continual pumping will cause a loss of such 'subflow' as to affect the quantity of the stream." *Id*. at 66.

The trial court described the testimony of Dr. Montgomery and Messrs. Ford and Page regarding reversal of hydraulic gradient:

> As Montgomery admitted, stream depletion occurs as soon as the "cone of depression" reaches the stream, even though it may be some time before the hydraulic gradient at the river is reversed, and may be many years before a particle travels from the stream to the well. (citation to transcript omitted). Ford and Page contend that streamflow depletion first takes place when the cone intersects the stream, not when the hydraulic gradient is reversed or the molecule of streamflow is ejected by the well. (citations to transcript omitted). <u>It is beyond dispute that even before the gradient is reversed, a measurable drawdown at the stream's "subflow" zone necessarily results in water leaving the zone in order to fill the void which has been created by the well</u>. Ford's Report, (citation omitted) [when the cone intersects the "subflow" zone, it "induce[s] subflow to leave (deplete the Subflow Zone and the stream")]. <u>This is true even where the gradient has not been reversed everywhere between the well and the stream</u>.[186] (Emphasis added.)

Gila IV affirmed the trial court's order in all respects and held that a well located outside the subflow zone will be included in the adjudication if "the well's cone of depression extends into the subflow zone and is depleting the stream."[187]

The Special Master interprets the trial court's ruling and its affirmance in *Gila IV* to hold that hydraulic gradient reversal, or that the gradient is continuously inclined from the subflow zone to the well, is not required to determine if a well's cone of depression is withdrawing appropriable subflow. A cone of depression test, however, must yield results with a high degree of reliability, and although gradient reversal is not required under *Gila IV* to include a well in the adjudication, its consideration will increase the reliability of a questionable cone of depression test. ADWR should proceed with its proposal to investigate water levels in wells and in the subflow zone during pumping and the extent of hydraulic gradient reversal, but the trial court should not adopt ADWR's second condition as a requisite for including a well in the adjudication.

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[186] *Id*. at 61.
[187] 198 Ariz. at 343, 9 P.3d at 1082.

Recommendation 22: The Court should not adopt as a condition to include a well in the adjudication that the water level in the well is below the water level in the subflow zone during pumping.

Recommendation 23: The Court should not adopt as a condition to include a well in the adjudication that the hydraulic gradient is continuously inclined from the subflow zone to the well.

C. What is the accuracy and reliability of analytical (THWELLS) and numerical (MODFLOW) models for the cone of depression test?

ADWR proposes to use both analytical and numerical models for the cone of depression tests. Models are sets of mathematical flow equations whose solutions yield simulations of the behavior of aquifers in response to stresses. ADWR recommends using an analytical computer-based program called THWELLS (van der Heijde, version 4.01, 1996) to evaluate a well's cone of depression where "the aquifer system is less complex and the flow equations can be solved directly using calculus."[188] ADWR recommends that a numerical model called MODFLOW (McDonald and Harbaugh, 1988; Harbaugh and McDonald, 1996) "only be used to evaluate the cone of depression of a well in special circumstances where, based on the conceptual model, the aquifer system is exceedingly complex and the flow equations can only be solved by recasting them in algebraic form."[189] ADWR does not indicate what percentage of the cone of depression tests will be done using each model.

ADWR has considered economy and expediency to select a computer-based model it believes will yield simulations with a high degree of reliability in different aquifer systems. In support of its recommendations, the department explains that:

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[188] Subflow Report 28; app. G of the report contains a description of the THWELLS program.
[189] *Id*. at 29; app. H of the report contains a description of the MODFLOW program. "Currently, MODFLOW is the most widely used program in the world for simulating ground-water flow." *Id*. app G, Fact Sheet, 1.

1. Analytical models "can be constructed relatively quickly" using commercially available computer software such as THWELLS.[190]

2. "[D]evelopment of numerical models is still a very time consuming process that requires substantial field data to justify its use and to properly calibrate."[191]

3. Both models will give approximate solutions to the mathematical flow equations used in each program.

The testimony elicited the following regarding THWELLS and MODFLOW:

1. Mr. Mason, manager of ADWR's Groundwater Modeling Unit, testified that an analytical model assumes an isotropic homogeneous aquifer (as opposed to heterogeneous).[192] There are aquifers in the San Pedro River Watershed that are not homogeneous. In aquifers where the "geology or the hydrology [is] complicated," ADWR would use a numerical model.[193]

2. Mr. Mason testified that an analytical model assumes an aquifer has an infinite areal extent.[194] On the other hand, a numerical model divides an aquifer into rectangular blocks which are then organized by rows, columns, and layers. Each block is called a cell. THWELLS assumes a single model cell or block in infinite dimensions, while MODFLOW can consider numerous cells. Dr. Montgomery and Mr. Anderson declared that "both tributary aquifers and Holocene alluvial aquifers in Arizona stream valleys are of limited rather than infinite extent."[195]

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[190] *Id*. at 29.
[191] *Id*.
[192] Hrg. Tr. 98:16-18 (Oct. 21, 2003).
[193] *Id*. at 93:16-18; 116:3-5. Mr. Burtell, for example, testified that in a preliminary appraisal of the water development potential of a mine in Tombstone, located in the San Pedro River Watershed, he had recommended using a numerical model due to the mine's bedrock aquifer system. *Id.* at 45:19-46:5.
[194] *Id*. at 98:19-20.
[195] Errol L. Montgomery and Thomas W. Anderson Decl. 23 (June 17, 2002). They also declared that "[f]ew aquifers may approach homogeneous conditions." *Id.*

3. A greater number of cells allows a numerical model to account better than an analytical model for geologic deposits (such as inliers, relic fan deposits, or bedrock) that come through but are not floodplain Holocene alluvium because these deposits can be anticipated with individual cells.[196]

4. In a numerical model, each well can be placed in its own cell and its cone of depression analyzed. Such a cell "could be very small."[197]

5. The greater the number of cells used in a numerical model the higher is the likelihood of data entry errors and the difficulty of managing the information.[198]

6. In a numerical model, although it would be difficult to implement, cells can be included or excluded ("turned on and off") from different test runs.[199]

7. Mr. Mason testified that "with THWELLS" the modeler uses "whatever data you have available," and "you really can't calibrate" THWELLS.[200] Calibration is a way to see if the model applied to a field situation is an acceptable representation.

8. A numerical model such as MODFLOW is calibrated with hydrologic or well information obtained from field investigations or reliable sources, and is run until its results agree with the calibrating data ("until the model agrees with the real world").[201]

9. Dr. Mock declared it is not true "that only numerical models should be calibrated," and "[c]alibration should be required of both analytical and numerical models."[202]

10. Both THWELLS and MODFLOW "require information for aquifer hydraulic parameters of hydraulic conductivity and storage coefficient, saturated thickness of the aquifer, pumping rate of

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[196] Hrg. Tr. 165:14-23 (Oct. 21, 2003).
[197] *Id*. at 166:2-9; 88:7-11.
[198] *Id*. at 88:7-11; *see also* Jon R. Ford Rebuttal Decl. ¶¶ 12, 13 (June 27, 2003).
[199] Hrg. Tr. 88:17-23; 166:22-167-6 (Oct. 21, 2003).
[200] *Id*. at 81:20-21.
[201] *Id*. at 69:23-24; 81:23.
[202] Peter A. Mock Decl. 26 (June 17, 2002); Messrs. Harmon and Palumbo agreed with this opinion.

the well, duration of pumping, and distance from the well to the point where drawdown is to be estimated."[203] The Subflow Report describes how the department plans to obtain and use these data. The information is not always available or reliable, and its interpretation may require considerable professional judgment and expertise.

11. Mr. Ford testified that THWELLS "doesn't take into account very well the effects of phreatophytes" or of recharge from either precipitation or basin fill aquifers.[204] Recharge includes artificial recharge.

12. Dr. Mock testified it could cost "in the range of $250,000 to $500,000 to develop" a MODFLOW model for either the upper or lower portions of the San Pedro River Watershed.[205] This estimate is to develop the model and does not include some operational costs such as sensitivity analysis. His "rough approximation" for a similar THWELLS model is "[p]erhaps half the cost."[206]

The parties split between those who favor using exclusively a numerical model for the cone of depression test, and those who believe ADWR has the expertise to select the appropriate model for an aquifer system and should be allowed to do so. ADWR uses both analytical and numerical models in its statutory activities. It has developed numerical models for the San Pedro River Watershed. In the Final San Pedro River Watershed HSR (1991), ADWR presented a MODFLOW analysis assessing the cumulative impact of eight municipal water companies on the aquifers near Fort Huachuca and the San Pedro Riparian National Conservation Area.

Mr. Harmon testified that:

> There may be physical situations where the geology is fairly simple. The hydrology is not complex. There are not a lot of recharge inputs or discharge outputs; and in that case the analytic model might be just fine….

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[203] Errol L. Montgomery and Thomas W. Anderson Decl. 21 (June 17, 2002).
[204] Hrg. Tr. 260:7-18 (Oct. 22, 2003); 107:1-5 (Oct. 21, 2003).
[205] *Id*. at 405:17 (Oct. 22, 2003).
[206] *Id*. at 406:14-16.

> In other instances and I think in my opinion many instances the geology is complex, heterogeneous. There are lots of inputs and outputs, gradients to the water table which may be in multiple directions and slopes. In that instance, it would probably take a well-calibrated MODFLOW model with good data to back it up….
>
> QUESTION. So it will be different depending on the situation.
>
> ANSWER. I believe it would.[207]

Responding to when THWELLS or MODFLOW should be used, Mr. Ford testified:

> [I]t depends on the situation. There may be places where it makes very little difference whether you use THWELLS, MODFLOW. THWELLS in my view would be far less expensive to utilize. I think in those cases then THWELLS should be used.
>
> I think DWR has the ability to make those professional decisions….[208]

Because ADWR recommends modeling for the cone of depression test, whether an analytical or a numerical model will be used is a critical component of the cone of depression test. The selection must be subjected to the criteria set forth in *Gila IV* for the cone of depression test, namely, the model should be (1) "realistically adaptable to the field," (2) "is the least expensive," (3) the least "delay-causing," and (4) "provides a high degree of reliability."[209]

The evidence does not support a finding that ADWR should use a numerical model or MODFLOW as the exclusive model for the cone of depression test. The evidence shows an analytical model is valid for a cone of depression test where the aquifer system is homogeneous, hydrologic conditions are simple, and the required information is reliable. For those aquifer systems, an analytical model like THWELLS would be the least expensive and delay-causing model, realistically adaptable to the field, that will provide highly reliable results.

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[207] *Id*. at 368:17-369:5.

[208] *Id*. at 266:17-20; Messrs. Harmon and Palumbo declared, "[t]he possible use of these two models in cone of depression analyses is not an issue. However, the proper selection of one model or the other in the analysis of a particular well is a significant issue." Eric J. Harmon and Mark R. Palumbo Decl. 30 (June 17, 2002).

[209] 198 Ariz. at 343, 9 P.3d at 1082 (quoting Goodfarb Order 62).

The evidence, however, shows that a numerical model such as MODFLOW will provide a higher degree of reliability than an analytical model when the aquifer system is heterogeneous or when an analytical model cannot take into account very well certain conditions, for example, phreatophytes and artificial or natural recharge.

ADWR has the expertise and experience to conduct cone of depression tests. The department should be allowed to exercise its best professional judgments and technical analysis to utilize the most appropriate model that satisfies *Gila IV's* criteria for the cone of depression test. ADWR should, however, undertake an ongoing program to collect and obtain reliable information to use in the cone of depression tests. Regarding calibration, the Special Master finds that analytical and numerical models can be calibrated, calibration increases the reliability of results, and accordingly, ADWR should calibrate both models whenever feasible.

The majority of the experts expressed a preference for numerical models. The Special Master believes ADWR should use MODFLOW or a numerical model whenever there is professional doubt that THWELLS will not yield reliable results. Economy and expediency should not win over appropriate and prudent professional decisions, as what is gained today could be lost tomorrow in increased litigation over flawed assumptions or inadequate work. The decision to switch from an analytical to a numerical model in a particular situation should not be finessed.

Recommendation 24: The Court should adopt ADWR's proposal to use both analytical (THWELLS) and numerical (MODFLOW) models for the cone of depression tests.

Recommendation 25: The Court should direct ADWR to implement promptly any new versions of THWELLS or MODFLOW, if they will provide more reliable results.

Recommendation 26: The Court should direct ADWR to calibrate whenever feasible both the analytical and numerical models used for the cone of depression tests.

Recommendation 27: The Court should direct ADWR as part of its investigations to collect and obtain reliable information for the cone of depression tests.

D. Is ADWR's recommendation that the impact of a well be measured *"at the time of the modeling"*[210] scientifically valid?

ADWR recommends that the impact of a well on the subflow zone be measured at the time ADWR does the cone of depression test. ADWR proposes to run the cone of depression test for a well beginning on the date the well was constructed and ending on the date the modeling is done.[211] The test will not measure the future impact of a cone of depression. After the time of modeling, the well's cone of depression could stabilize, expand into the subflow zone, or decrease if, for example, the well is capped. These effects occur gradually.[212] ADWR's test is called transient state modeling.

The Subflow Report does not give ADWR's reasons for the recommendation. Mr. Mason provided a reason when he testified that ADWR's proposal does not include future impacts of a well "because we don't know what's going to happen in the future."[213]

The parties favoring measuring future impacts argue that a well may not impact the subflow zone on the day ADWR does the cone of depression test, but the well may do so in the near future. Therefore, not measuring future impacts will result in many wells being excluded from the adjudication even though they will pump subflow at a future time. Although these wells could be retested later, these parties argue that ADWR may not have the resources to do ongoing cone of depression tests in the same watershed, and second, claimants should not be burdened with prosecuting enforcement actions to bring those wells into the adjudication.

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[210] Subflow Report 31.
[211] Hrg. Tr. 115:18-23 (Oct. 21, 2003).
[212] *See* Goodfarb Order 59-60; *see also* T. Allen J. Gookin Decl. sec. 3, 1-2 (June 17, 2002).
[213] Hrg. Tr. 90:1-5; 102:22-23 (Oct. 21, 2003).

The parties on the other side of this issue argue that, as Mr. Mason testified, the future is unknown, and pumping histories and water uses can vary over time; consideration of time of pumping is not necessary as long as data obtained from monitoring wells shows the groundwater gradient has reversed; and wells presently not pumping appropriable subflow would be improperly included in the adjudication on the ground they may impact the subflow zone at a future time.

Parties presented three alternatives for the length of simulations that will account for future impacts: (1) a fixed period such as five, ten, or twenty years,[214] (2) the timing of maximum drawdown at the subflow zone,[215] and (3) modeling to steady state conditions.[216]

The five-year period is related to ADWR's well spacing standard of ten feet of drawdown over five years to determine if a well will interfere with another well in an active management area. Measuring a well's potential interference with a nearby well is, however, not the same as measuring the impact of a cone of depression on the subflow zone in accordance with *Gila IV's* holdings, and moreover, a ten-foot drawdown would be measured long after a well's cone of depression has induced water out of the subflow zone.

Only Dr. Montgomery and Mr. Anderson declared in favor of using a period of ten or twenty years, and their evidence was limited to the statement that, "this period is sufficiently long to exclude wells that pump small amounts but is sufficiently long to assure that most large-scale pumping wells would be included in the adjudication if the cone of depression reaches the edge of subflow."[217] Dr.

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[214] Errol L. Montgomery and Thomas W. Anderson Decl. 8, 25 (five years) (June 17, 2002); Errol L. Montgomery and Thomas W. Anderson Rebuttal Decl. 25 (ten and twenty years) (June 27, 2003).

[215] Peter A. Mock Decl. 26 (June 17, 2002); *see* Errol L. Montgomery and Thomas W. Anderson Rebuttal Decl. 24 (June 27, 2003) for their opinion that Dr. Mock "believes…model projections should be run until at least the year 2100."

[216] Oliver S. Page, Peter M. Pyle, and Jean M. Moran Decl. 25 (June 17, 2002). Mr. Toy testified, "[i]f you wanted to see the ultimate effect a well had, you would pump it to steady state." Hrg. Tr. 397:4-5 (Oct. 22, 2003).

[217] Errol L. Montgomery and Thomas W. Anderson Rebuttal Decl. 25 (June 27, 2003).

Mock recommended the timing of maximum drawdown with the declaration that it "would be a better measure of minimum time for simulation and should be, as the impact on flows will be, dependent on the local conditions."[218] No further evidence was presented on these alternatives.

Mr. Page and Dr. Mock criticized ADWR's time of the modeling and assigning a fixed period to all simulations because these periods are arbitrary. Underlying this argument is the position that cones of depression can expand over time, and expanding cones of depression can have substantial impacts on the subflow zone and aquifers. In its 1994 order, the trial court described some of the "destructive ability" of cones of depression in desert and semi-desert environments.[219] Under these experts' view, a test that does not consider the future impact of a cone of depression is arbitrary and "unrealistic" because it "ignores the concept that, eventually, impacts will be felt."[220]

More evidence was presented regarding the proposal that all simulations be run as steady state or long enough to approximate steady state conditions. Mr. Page explained the benefits of using a steady state model:

> The term steady-state refers to an equilibrium hydrologic condition where…an equilibrium is established between the pumping well, and the amount of water they pump that is obtained from streams, recharge and underground water storage. In steady-state, these are constant and do not change over time. Usually long term average hydrology is used as input. Time is not an input to the model, eliminating the need to define a specific time period.
>
> This approach…addresses the fact that the period of future use of wells (or their replacements) cannot be predicted, but is important to the cumulative impact of wells on subflow. This approach also simplifies the issue of how to assess the impact of future wells drilled due to growth….

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[218] Peter A. Mock Decl. 26 (June 17, 2002).
[219] Goodfarb Order 59-60.
[220] T. Allen J. Gookin Rebuttal Decl. ch. XIV 1, 2 (June 27, 2003).

> The use of steady-state simulations as a means for evaluating wells will result in a greater number of wells that have cones of depression that intersect the subflow boundary.[221]

Mr. Page declared that steady state simulations are "available to all numerical and <u>some</u> analytical models."[222] (Emphasis added.) It is not known if the steady state simulations are available for the THWELLS analytical model ADWR proposes to use.

Regarding a steady state model, Messrs. Harmon and Palumbo declared that:

> 1. The calibration of a steady state model "is, in general, not nearly so rigorous as the time-varying calibration done in transient modeling" because "time-varying inputs are simply averaged," so "generally there is less reliability with the result;"
>
> 2. A steady state model "is not able to simulate [the] dynamic [hydrologic] system" in Southwestern deserts, where "streamflow, precipitation, long-term climate variation, and water level changes" are dynamic; and
>
> 3. A steady state model "ha[s] no provision for simulating the changes in ground water storage" resulting "from changes in ground water level and artesian head."[223]

The resolution of this issue turns not only on the evidence but also on *Gila IV's* holdings. In *Gila IV*, the Supreme Court affirmed the trial court's ruling that:

> [A] well may be subject to the adjudication if its "'cone of depression' caused by its pumping has <u>now</u> extended to a point where it reaches an adjacent 'subflow' zone, and by continual pumping will cause a loss of such 'subflow' as to affect the quantity of the stream."
>
> DWR may seek to establish that a well located outside the limits of the saturated floodplain alluvium is in fact pumping subflow and is therefore subject to the adjudication, by showing that the well's cone of depression <u>extends</u> into the subflow zone and <u>is</u> depleting the stream.[224] (Emphasis added.)

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[221] Oliver S. Page, Peter M. Pyle, and Jean M. Moran Decl. 25-26 (June 17, 2002).
[222] *Id*. at 25.
[223] Eric J. Harmon and Mark R. Palumbo Rebuttal Decl. 22 (June 27, 2003).
[224] 198 Ariz. at 343, 9 P.3d at 1082 (quoting Goodfarb Order 66). The ruling is based on the trial court's seventh principle discussed in chapter 3, section B, of this report.

The Special Master interprets this holding and the pivotal underlined words to mean that a well will be subject to the adjudication if (1) ADWR determines the well's cone of depression has already extended, and not that it may in the future extend, into the subflow zone, and (2) if the well, after its cone of depression has extended into the subflow zone, continues to be pumped, stream flow will be affected appreciably and directly. This holding does not support using a cone of depression test that projects the future impact of a cone of depression. The cone of depression test, under *Gila IV*, is to determine if a well's cone of depression has "now" extended to the subflow zone and "is depleting the stream."

Considering the evidence only, the Special Master finds that it is insufficient to conclude that cone of depression simulations using a fixed period of five, ten, or twenty years projected into the future will yield more reliable results than either ADWR's time of the modeling or any other set period of years. The Special Master further finds that if the future impact of a cone of depression is excluded as a consideration, the evidence is insufficient to conclude that a steady state model will yield more reliable results than ADWR's proposed time of the modeling cone of depression test. The Special Master finds that ADWR's recommendation to measure the impact of a well at the time of the modeling is scientifically valid.

Although *Gila IV* and the evidence do not support rejecting ADWR's recommendation, the impact of expanding cones of depression must be taken into account. The hydrologic reality that cones of depression can grow and substantially impact the subflow zone and aquifers cannot be overlooked.

The Special Master recommends that ADWR be directed to complete additional cone of depression tests in a watershed at a time to be determined by the trial court or the Special Master that is appropriate to identify old or new wells that impact the subflow zone at that time. Because cone of depression tests are labor intensive, the additional tests may exclude wells, even ones previously tested, under guidelines adopted by the trial court or the Special Master.

Recommendation 28: The Court should adopt ADWR's recommendation that the impact of a well be measured at the time of the modeling.

Recommendation 29: The Court should direct ADWR to complete additional cone of depression tests in a watershed at a time to be determined by the trial court or the Special Master that is appropriate to identify old or new wells that impact the subflow zone at that time. The additional tests may exclude wells, even ones previously tested, pursuant to guidelines adopted by the trial court or the Special Master.

E. Should ADWR recommend a methodology to evaluate the impact of wells perforated below an impervious formation within the limits of the subflow zone?

The department does not recommend a methodology. The parties who briefed this issue do not believe ADWR needs to recommend a methodology, and no evidence was presented which could provide one. Mr. Page declared that a "method is needed," and "[s]tudies by the USGS and others have shown that wells are likely to affect the flow of the river, but may not result in identifiable drawdown in the floodplain alluvium," but hardly any evidence was presented on this issue.[225]

The genesis of this issue is *Gila IV's* holding that:

> All wells located in the lateral limits of the "subflow" zone are subject to the jurisdiction of this adjudication no matter how deep or where these perforations are located. However, if the well owners prove that perforations are below an impervious formation which preclude[s] "drawdown" from the floodplain alluvium, then that well will be treated as outside the "subflow" zone.[226]

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[225] Oliver S. Page, Peter M. Pyle, and Jean M. Moran Decl. 26 (June 17, 2002).

[226] 198 Ariz. at 338, 9 P.3d at 1077. This holding stemmed from the sixth of the seven principles the trial court deemed necessary to define the subflow zone. The principle was, "[w]ells which are located in but perforated below the saturated floodplain alluvium aquifer are to be included in the 'subflow' component unless these perforations are proven by their owners to be below a confining zone of impermeable material such as clay as the inevitable 'draw-down' of the well must affect the 'subflow zone' above the perforation." Goodfarb Order 36. The six principles are discussed in chapter 2, section D, and in chapter 3, section B, of this report.

Because *Gila IV* makes it clear that the well owner has the burden of proving that a well though punched in the subflow zone is not withdrawing water from the saturated floodplain Holocene alluvium but from an aquifer below an impervious formation, the well owner should formulate and present a methodology. The fact the well owner has this burden of proof does not mean that the trial court or the Special Master cannot ask ADWR to provide them technical assistance concerning the merits of a particular methodology.

Recommendation 30: The Court should not direct ADWR to recommend a methodology to evaluate the impact of wells perforated below an impervious formation within the subflow zone.

F. In addition to analyzing a well's drawdown at the subflow zone, should ADWR report the cumulative effect of wells or of groups of wells?

This question was briefed prior to the hearing. A ruling was issued on September 8, 2003, subject to modification after considering the evidence presented during the hearing. The proposed ruling is adopted in part and modified in part.

The Special Master determined that a well's drawdown at the subflow zone shall be analyzed individually for each well but deferred ruling on whether ADWR should report the cumulative effect of wells or of groups of wells until after considering the evidence presented at the hearing.

In *Gila IV*, the Supreme Court stated that the trial court "recognized that each well must be separately evaluated 'to compute drawdown at the "subflow" zone'... We agree with the trial court."[227] The trial court had considered the testimony of Mr. Ford and Dr. Montgomery, who had "agreed that individual analysis of wells is the most appropriate method to compute drawdown at the 'subflow' zone."[228] Therefore, under *Gila IV* a well's impact on the subflow zone must be individually evaluated for each well, and this portion of the proposed ruling is not modified.

[227] 198 Ariz. at 343, 9 P.3d at 1082.
[228] Goodfarb Order 62.

The challenging inquiry is whether ADWR should go further after analyzing each well and report the cumulative effect of wells or of groups of wells. *Gila IV* is silent on this issue. Dr. Mock's declaration highlights the concern some parties emphasize: "The potential exists for hundreds of wells to individually pass ADWR's proposed cone of depression test at the current time and yet the group of wells could collectively have significant impacts on river flows at a later time."[229] Mr. Page declared that "[w]hile individual wells may not have an instantaneous and measurable effect on stream flow, they can have a significant impact over time, particularly when combined with the effects of hundreds of other wells."[230]

Implicit in an answer to the question are the expectations that ADWR will be able to obtain reliable information about cumulative effect, if any, and that it will be able to do so with a test that "is realistically adaptable to the field and…is the least expensive and delay-causing, yet provides a high degree of reliability…."[231] The realities of these expectations are not clearer today than they were prior to the hearing.

The Subflow Report does not contain scientific or technical information to form the basis of a methodology to evaluate cumulative effect, as the report does not directly address this issue, and the evidence is insufficient to formulate criteria to analyze cumulative effect. The desire of some parties that ADWR report cumulative effect is well-stated, but how ADWR should undertake the analysis that "provides a high degree of reliability" is not clear.

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[229] Peter A. Mock Decl. 4 (June 17, 2002); *see also* T. Allen J. Gookin Decl. sec. 3, 1-2 (June 17, 2002). After describing the testimony about wells located outside the subflow zone whose cones of depression "could severely affect the volume of stream flow and the 'subflow' which supported it," the trial court noted that "[o]ften those wells had extensive and interconnecting 'cones of depression.'" Goodfarb Order 60. Tucson commented that the "collective impact of many *de minimis* users" concentrated in areas with an unusually narrow and very shallow subflow zone "could have an appreciable effect on a subflow zone" and appropriative water right holders. Response to ADWR's Subflow Report 5 (June 17, 2002).

[230] Oliver S. Page Rebuttal Decl. 11 (June 27, 2003).

[231] 198 Ariz. at 343, 9 P.3d at 1082 (quoting Goodfarb Order 62).

In this discussion, other important considerations must be weighed. The complexity of cone of depression analysis involving "numerous assumptions and considerable judgment,"[232] the number of wells that may require individual analysis,[233] and the time-sensitivity of cone of depression tests dictate that the task not be overly complicated. ADWR estimates that within the San Pedro River Watershed "several hundred cone of depression tests would have to be performed," and "it takes one person working full time to make about 50 to 60 model runs using THWELLS in one year."[234] The cone of depression tests should be completed within a practical period of time and must yield results with a high degree of reliability. Undertaking a comprehensive analysis of cumulative effect, in addition to individual effects, could impracticably expand the technical investigations and thwart their success.

In its closing brief, the United States indicated the USGS expects to finish in 2005 a study of the hydrology of the Sierra Vista Subwatershed that "once completed," ADWR could use "to examine the effects of pumping from individual wells <u>and</u> the cumulative effects of pumping from groups of wells (footnote omitted)."[235] (Underlining in original.) The United States submits that the study "may provide the answer to the Special Master's remaining question" about ADWR reporting cumulative effect.[236]

At the oral argument, the idea of ADWR doing certain analyses of cumulative effect and reporting its findings was discussed. The purpose would be to collect data regarding cumulative

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[232] Subflow Report 21-22.

[233] According to Mr. Page, using 2001 data, there are 5,370 *de minimis* domestic wells (out of 5,413 wells) and 1,066 *de minimis* stockwatering wells (out of 1,076 wells). In the Final San Pedro River Watershed HSR, ADWR, using 1990 data, reported 2,990 *de minimis* domestic wells and 72 *de minimis* other uses wells. The number of wells has increased significantly since 1990. Oliver S. Page, Peter M. Pyle, and Jean M. Moran Decl. 30, 32 (June 17, 2002).

[234] Subflow Report 22, 43.

[235] U.S. Memo. on Issues Related to ADWR's Subflow Technical Report 5-6 (Mar. 3, 2004).

[236] *Id*. at 6.

effect so that the court's and the parties' understanding would be increased. Whether the findings will be, or should be, used to adjudicate any water uses is not addressed in this report. If ADWR is going to do cone of depression analyses, doing a cumulative effect analysis on selected groups of wells and obtaining observational and scientific information would be useful.

The Special Master recommends that ADWR select more than one group of wells, analyze their cumulative effect using the most accurate and reliable analytical or numerical models, and report the findings regarding cumulative effect, if any. The wells may be owned or used by one or several claimants, and the cone of depression analysis should provide information and data about cumulative effect. ADWR should research the scientific literature, review studies such as those the USGS expects to complete for the Sierra Vista Subwatershed, and build a body of knowledge.

Recommendation 31: The Court should direct ADWR to analyze a well's drawdown at the subflow zone individually for each well.

Recommendation 32: The Court should not direct ADWR to report the cumulative effect of wells or of groups of wells except as suggested in the next recommendation.

Recommendation 33: The Court should direct ADWR to select more than one group of wells, analyze their cumulative effect using the most accurate and reliable analytical or numerical models, and report the findings. The wells may be owned or used by one or several claimants, and the cone of depression analysis should provide information and data about cumulative effect. The purpose of these analyses is to build a body of knowledge about the cumulative effect of wells, including methodologies and findings. Whether the findings will be, or should be, used to adjudicate water uses is not determined in this report.

Recommendation 34: The Court should adopt Chapter 3 of the Subflow Report to the extent it does not conflict with any other recommendation made in this report.

IV. *DE MINIMIS* USES (Chapter 4 of the Subflow Report)

The trial court directed ADWR to submit a "set of rational guidelines for determining whether a given well, though pumping subflow, has a de minimis effect on the river system."[237] Little posthearing briefing was submitted regarding guidelines for *de minimis* water uses in the San Pedro River Watershed, the reason most likely being that after ADWR filed the Subflow Report, the trial court ruled on this issue with respect to instream stockwatering, stockponds of a certain size and beneficial use, and household domestic water uses.

In the Subflow Report, ADWR summarizes the proceedings Special Master John E. Thorson held from 1993 to 1995 addressing *de minimis* stockwatering, stockponds, and domestic water uses within the San Pedro River Watershed.[238] Special Master Thorson determined that instream stockwatering and stockponds and domestic uses meeting certain criteria should be considered *de minimis* water uses. The Subflow Report focuses on the determinations regarding *de minimis* domestic water uses because Special Master Thorson found that 97% of domestic uses in the San Pedro River Watershed were supplied from wells.[239]

ADWR believes that the "special master's proposed definition of *de minimis* domestic uses with a uniform quantification…is an acceptable definition," but disagrees with "the special master's determination that these *de minimis* uses should be summarily adjudicated with water rights characteristics."[240] ADWR recommends that *de minimis* domestic water uses "should be excluded

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[237] Ballinger Order 2.
[238] The contested case was *In re Sands Group of Cases (W1-11-19) and Other Related Cases (Consolidated)*. Special Master Thorson issued a Memorandum Decision, Findings of Fact, and Conclusions of Law for Group 1 Cases Involving Stockwatering, Stockponds, and Domestic Uses (Nov. 14, 1994) ("Memorandum Decision"), and a Modifying Memorandum Decision (Feb. 23, 1995).
[239] Memo. Decision 19 (Finding of Fact No. 22).
[240] Subflow Report 38.

from the adjudication and catalogued in the decrees."[241] Domestic wells determined to be *de minimis* would be listed in a catalog with basic descriptive information,[242] and "[a]s long as these catalogued domestic uses continued to satisfy the definition of a *de minimis* use adopted by the trial court, these uses would not be subject to post-decree administration or enforcement."[243] *De minimis* "uses would not receive a decreed water right."[244]

On September 26, 2002, nearly six months after ADWR filed the Subflow Report, the trial court adopted in part, rejected in part, and modified in part Special Master Thorson's memorandum decisions on *de minimis* stockwatering, stockponds, and domestic water uses in the San Pedro River Watershed. The trial court adopted the special master's definition of a *de minimis* domestic water use and the quantity to be adjudicated for the right. Special Master Thorson defined *de minimis* domestic water uses as "[i]ndividual domestic uses for single residences, when serving household purposes and associated outdoor activities on adjoining land not exceeding (=) 0.2 acres," and determined that "[t]he quantity of 'not to exceed 1 ac-ft/yr' of water will be adjudicated for" those rights.[245]

The trial court also adopted Special Master Thorson's definitions and quantifications for instream stockwatering and stockponds having a capacity of not more than 15 acre-feet used solely for stock or wildlife. The trial court directed ADWR to prepare future HSRs in accordance with the determinations adopted in the September 26, 2002, order.

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241 *Id*. at 40.
242 "The *de minimis* category would list the name of the present well owner, the well location to the nearest ¼ ¼ ¼ section, the type of use (domestic *de minimis*), the place of use, and the quantity of use." *Id*. The proposed catalog appears to be similar to Volume 8: *Catalogued Wells* of the Final San Pedro River Watershed HSR. Volume 8, however, reported for each listed well, if available, a "claimed date of first beneficial water use" and the "data source" of the reported information. Vol. 8, 6. Bella Vista agrees with ADWR but recommends that every well be catalogued using only the information required by A.R.S. § 45-596 to be set forth in a notice of intention to drill well. Comments on ADWR's Subflow Report 9 (June 17, 2002). The statute enumerates more information than ADWR recommends reporting in its proposed catalog.
243 Subflow Report 40.
244 *Id*. at 44.
245 Memo. Decision 33 (Conclusions of Law No. 24 and No. 25).

ADWR recommends that *de minimis* water uses be catalogued and not be summarily adjudicated with water right attributes. It points to the holdings in *Gila II* that "the trial court may adopt a rationally based exclusion for wells having a de minimis effect on the river system,"[246] and in *Gila IV* that wells though pumping subflow which "have a de minimis effect on the river system may be excluded from the adjudication based on rational guidelines for such an exclusion…."[247] In *Gila II*, the Supreme Court held that "[a] properly crafted de minimis exclusion will not cause piecemeal adjudication of water rights or in any other way run afoul of the McCarran Amendment…it could simplify and accelerate the adjudication by reducing the work involved in preparing the hydrographic survey reports and by reducing the number of contested cases before the special master."[248] ADWR submits that a catalog listing *de minimis* water rights is consistent with *Gila II* and *Gila IV* because exclusion does not include summary adjudication.

Special Master Thorson had the benefit of *Gila II* when he began (one month after *Gila II* was issued) the consolidated case that resulted in his memorandum decisions. In *Gila II*, the Supreme Court held that "a de minimis exclusion effectively allocates to those well owners whatever amount of water is determined to be de minimis. It is, in effect, a summary adjudication of their rights."[249] (Emphasis added.) Special Master Thorson adopted procedures for the "summary adjudication" of *de minimis* uses. The procedures provided for the preparation of water right abstracts showing the characteristics or attributes of *de minimis* uses; incorporation of the abstracts into the special master's catalog of proposed water rights for the watershed; allowing claimants to file objections to the abstracts but precluding resolution of objections concerning quantity of water; and incorporation of

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[246] 175 Ariz. at 394, 857 P.2d at 1248.
[247] 198 Ariz. at 344, 9 P.3d at 1083.
[248] 175 Ariz. at 394, 857 P.2d at 1248.
[249] *Id*.

all *de minimis* water rights in the final decree which would subject the rights to post-decree administration and enforcement against other water uses.[250]

Special Master Thorson concluded that these "summary procedures for *de minimis* uses accomplish the statutory purposes of the general stream adjudication to '[d]etermine the extent and priority date of and adjudicate any interest in or right to use the water of the river system and source .… ARIZ. REV. STAT. ANN. § 45-257(B)(1)."[251] He defined the term "summary adjudication" to mean "those procedures used by the court to adjudicate *de minimis* water uses in a simplified and expedited manner while safeguarding the statutory and due process rights of the litigants involved."[252]

In its September 26, 2002, order the trial court specifically adopted Special Master Thorson's definition of "summary adjudication" and ruled that "summary adjudication is appropriate to determine the attributes and characteristics of water uses that do not individually affect the water supply available to other claimants."[253] The trial court has answered the issue ADWR's recommendation raises. *De minimis* water uses within the San Pedro River Watershed will be summarily adjudicated with water right attributes and will receive a decreed water right.

A group of parties urges that ADWR be directed to propose guidelines for excluding agricultural, municipal, industrial, and other wells, not just domestic wells, which may have a *de minimis* effect on the river system.[254] This issue will best be considered at such time as ADWR and the parties have more new or updated data.

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[250] Memo. Decision 34-8 (What Summary Adjudication Procedures Are Appropriate?).
[251] *Id*. at 37; *see* A.R.S. § 45-252(A).
[252] *Id*. at 5.
[253] Order n.2, 2.
[254] Upper Valley Irrigation Districts' Objection to ADWR's Subflow Report 11 (June 17, 2002).

Other Watersheds

The argument has been made that the definitions of *de minimis* water uses "should be based on watershed specific tests to reflect the unique characteristics of each watershed…."[255] Special Master Thorson held a hearing to receive evidence specific to the San Pedro River Watershed regarding water availability in the watershed and to downstream users; the number of stockwatering, stockpond, and domestic uses; the number and impact of these uses; and the costs and benefits of adjudicating these water uses.[256] That matter integrated into the adjudication a practical concept of *de minimis* water uses and established procedures to define and adjudicate them. It is realistic to believe that a similar evidentiary hearing will be required in the other watersheds. The time to take up those issues is after the watershed HSR is filed. Some of the ground Special Master Thorson covered will not be revisited, but it is reasonable to believe that a watershed specific hearing will be necessary.

Recommendation 35: The Court should adopt Chapter 4 of the Subflow Report except the recommendation that *de minimis* uses not be summarily adjudicated with water right attributes, and to the extent Chapter 4 does not conflict with any other recommendation made in this report.

V. IMPLEMENTATION OF PROCEDURES (Chapter 5 of the Subflow Report)

A. Should ADWR's findings be reported in supplemental contested case hydrographic survey reports (HSRs) ("case-by-case") or in a supplemental San Pedro River Watershed HSR ("the entire watershed"), which identifies the subflow zone, wells reaching and depleting a stream, and *de minimis* water rights?

This was the fourth question briefed prior to the hearing, and a ruling was issued on September 8, 2003, subject to modification after considering the evidence presented during the hearing. The proposed ruling is adopted as the evidence is insufficient to modify it.

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[255] Philip C. Briggs Decl. ¶ 9 (June 17, 2002). Claimants in the Verde River Watershed raised this issue.
[256] Order 3 (Sept. 26, 2002).

The trial court directed ADWR to include "[a] timeline for completion of the tasks outlined in the report" and to submit "[a] similar timeline for the Upper Gila River and Verde River watersheds…."[257] In the proposed ruling, the Special Master found that the term timeline connotes a reporting schedule and with the desire to move the adjudication forward, set a schedule for ADWR to file a technical report containing a map of the lateral extent of the subflow zone within the entire San Pedro River Watershed; investigate and supplement, as needed, the Final San Pedro River Watershed HSR; and publish a supplemental final HSR. Claimants would have one hundred and twenty days to file objections to ADWR's report showing the map of the subflow zone, and one hundred and eighty days to file objections to the supplemental final HSR.

Some parties argue that under A.R.S. § 45-256(B) the technical assistance provided by ADWR must be set forth in a report filed with the trial court or the Special Master, and a claimant may file an objection to the report or any part of it within one hundred and eighty days of the date on which the report is filed. A.R.S. § 45-256(B) states in pertinent part:

> The technical assistance rendered by the director shall be set forth in summary form on a claim by claim basis in a report prepared by the director and filed with the court or the master…. The report shall list all information that is obtained by the director and that reasonably relates to the water right claim or use investigated. The report shall also include the director's proposed water right attributes for each individual water right claim or use investigated…. If no water right is proposed in connection with an individual water right claim or use, the director's recommendations shall so indicate…. An objection shall specifically address the director's recommendations regarding the particular water right claim or use investigated. (Emphasis added.)

The Special Master interprets A.R.S. § 45-256(B) to mean that the 180-day objection period applies to a report that contains the information ADWR has compiled during its investigations and sets forth the department's proposed attributes for each water right claim or use investigated. The 180-day period applies to a watershed or a supplemental contested case HSR that reports on

[257] Ballinger Order 3.

individual water right claims. The technical report to which all claimants in the San Pedro River Watershed will have one hundred and twenty days to file objections will not contain ADWR's proposed water right attributes for any claim or use. The report will contain ADWR's map of the subflow zone and related analysis. A report that covers a discrete, albeit important, technical issue is not subject to the time periods prescribed by A.R.S. § 45-256(B).

One party does not disagree with the Special Master's proposed schedule, but requests that it be recommended that in other watersheds ADWR divide a stream into manageable segments and publish a supplemental HSR that contains the subflow analysis for each stream segment. The "segment-by-segment" approach, is suggested, would be fair, efficient, and speedy.

A great amount of experience will be gained from going through the process of delineating the subflow zone in the San Pedro River Watershed. The segment-by-segment approach may have merit in other watersheds, but a decision in that respect should await the experience gained by going through the process in the San Pedro River Watershed. Although a recommendation regarding this approach is not made in this report, the parties may make suggestions when ADWR begins, or is in a position that it can undertake concurrently, the subflow analysis in another watershed.

ADWR recommends that for each watershed the subflow zone be identified first, followed by the identification of *de minimis* water uses, and concluding with the cone of depression tests. The second and third phases "should only be implemented when the watershed is ready to be litigated…."[258] This implementation sequence is reasonable.

ADWR does not propose a sequential watershed schedule, but based on the trial court's February 21, 2003, order and Pre-Trial Order No. 1 Re: Conduct of Adjudication ¶ 12(B)(4) (May 29, 1986), the Special Master recommends the following sequence for completing the subflow and

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[258] Subflow Report 45.

cone of depression analysis in each watershed: San Pedro River; Verde River; Upper Gila River; Upper Salt River; Upper Agua Fria River; Lower Gila River; and Upper Santa Cruz River.

Recommendation 36: The Court should implement the following schedule in the San Pedro River Watershed:

A. After the Court considers the Special Master's report recommending the procedures and processes to delineate the subflow zone within the San Pedro River Watershed and a cone of depression test, ADWR is directed to prepare a map delineating the subflow zone for the entire San Pedro River Watershed. ADWR shall submit this map and related information in a technical report whose scope shall be limited to delineating the subflow zone and shall not set forth ADWR's proposed water right attributes for any individual water right claim or use.

B. Upon filing the technical report with the Court, ADWR shall send a notice to all claimants in the San Pedro River Watershed and to the persons listed in the Gila River Adjudication Court-Approved Mailing List informing them of the scope and availability of the report and of a claimant's right to file written objections to the report and of the deadline for filing objections.

C. Any claimant in the San Pedro River Watershed may file objections to ADWR's technical report within one hundred and twenty days of the date on which the report is filed. Objections shall be limited to ADWR's findings regarding the lateral extent of the subflow zone.

D. After considering the objections, the Court will approve a map that delineates the subflow zone within the San Pedro River Watershed.

E. Using the cone of depression test adopted by the Court, ADWR will analyze all wells located outside the lateral limits of the subflow zone to determine if a well's cone of depression reaches an adjacent subflow zone, and if continuing pumping will cause a loss of such subflow as to affect the quantity of the stream. ADWR will examine all water right claims to determine *de minimis* water rights in the San Pedro River Watershed in accordance with the Court's September 26, 2002, order. ADWR will investigate and supplement, as needed, its findings reported in the Final San Pedro River Watershed HSR.

F. ADWR will publish a Supplemental Final San Pedro River Watershed HSR reporting its findings and proposed water right attributes on a claim by claim basis, in accordance with A.R.S. § 45-256(B), including wells withdrawing subflow, cone of depression analyses, *de minimis* water rights, and all other new or updated information.

G. ADWR shall send a notice of the filing of the Supplemental Final San Pedro River Watershed HSR to all claimants in the Gila River Adjudication, who may file objections within one hundred and eighty days of the date on which the report was filed.

Recommendation 37: The Court should adopt the same schedule for completing the subflow and cone of depression analysis in all the other watersheds in the Gila River Adjudication subject to modifications that may be proper as a result of experience with this process.

Recommendation 38: The Court should adopt the following sequence for completing the subflow and cone of depression analysis in each watershed: San Pedro River; Verde River; Upper Gila River; Upper Salt River; Upper Agua Fria River; Lower Gila River; and Upper Santa Cruz River.

Recommendation 39: The Court should adopt Chapter 5 of the Subflow Report to the extent it does not conflict with any other recommendation made in this report.

VI. AVAILABILITY OF REPORT

This report will be filed with the Clerk of the Maricopa County Superior Court, and a copy will be mailed to all persons listed on the Gila River Adjudication Court-Approved Mailing List and on those additional persons appearing in the certificate of service. An electronic copy will be posted at http://www.supreme.state.az.us/wm/ on the *Gila River Adjudication* page. A transcript of the October 21-22, 2003, hearing and of the evidence and the original exhibits are at the Clerk's office. A printed copy of this report can be purchased from the office of the Special Master for $8.00 payable by check or money order.

VII. MOTION FOR ADOPTION OF SPECIAL MASTER'S REPORT

The Special Master recommends adoption of the recommendations made in this report and moves the Court, under Arizona Rule of Civil Procedure 53(h), to adopt each recommendation. A proposed order of adoption will be lodged as the Court may order upon consideration of the report.

VIII. NOTICE OF SUBSEQUENT PROCEEDINGS

Any claimant in the Gila River Adjudication may file a written objection to this report on or before September 1, 2004.[259] Responses to objections must be filed on or before October 1, 2004. Replies must be filed on or before October 29, 2004. Each objection should identify the related recommendation. Objections, responses, and replies must be filed with the Clerk of the Maricopa County Superior Court, Attn: Water Case, 601 West Jackson Street, Phoenix, Arizona 85003. Copies of pleadings must be served personally or by mail on all persons appearing on the most recent Gila River Adjudication Court-Approved Mailing List and on those additional persons named in the certificate of service. The hearing on the Special Master's motion to approve the report and on any objections to the report will be taken up as ordered by the Court. The "court after hearing may adopt

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[259] The periods for filing objections to the report, responses, and replies are calculated under Ariz. R. Civ. P. 53(h). As this report does not contain determinations of the relative water rights of any claimant, the time periods prescribed by A.R.S. § 45-257(A)(2) do not apply. The period for filing objections includes the ten-day period provided by Rule 53(h), not including intermediate Saturdays, Sundays, and legal holidays as specified by Ariz. R. Civ. P. 6(a). The ten-day period for filing responses and the five-day period for filing replies are specified in Ariz. R. Civ. P. 7.1(a). An additional five-day period when service has been made by mail is specified in Ariz. R. Civ. P. Rule 6(e). In order to allow time for the distribution of the monthly docket sheet to subscribers and reasonable time for all filings, the Special Master has added thirty days for objections and fifteen days for responses and replies.

the report or modify it or may reject it in whole or in part or may receive further evidence or may recommit it with instructions."[260]

Submitted this 16th day of July, 2004.

/s/ George A. Schade, Jr.
GEORGE A. SCHADE, JR.
Special Master

The original report was filed with the Clerk of the Maricopa County Superior Court on July 16, 2004, and was delivered to the Distribution Center for mailing to the persons listed on the Gila River Adjudication Court-Approved Mailing List dated October 6, 2003 (Attachment A) and to the following persons:

City of Benson
Jennele Morris O'Hair, P.C.
P. O. Box 568
Vail AZ 85641-0568

Long Meadow Ranch Property Owners Association
George E. Price, President
12110 N. Antelope Run
Prescott AZ 86305

Valory Strausser
Lee A. Storey and Steve Wene
Moyes Storey, Ltd.
1850 N. Central Ave., Suite 1100
Phoenix AZ 85004

Yavapai County Attorney's Office
M. Randolph Schurr
255 East Gurley St., 3rd Floor
Prescott AZ 86301

/s/ KDolge
Kathy Dolge

[260] Ariz. R. Civ. P. 53(h).

SUPERIOR COURT OF ARIZONA
MARICOPA COUNTY

09/15/2005 CLERK OF THE COURT
FORM V000

HONORABLE EDDWARD BALLINGER, JR. M. Wetherell
Deputy

W-1, W-2, W-3, W-4(Consolidated)
Contested Case No. W1-103

FILED: **September 28, 2005**

In Re the General Adjudication
of All Rights to Use Water in
The Gila River System and Source

In Re Subflow Technical Report,
San Pedro River Watershed

Order Re: Report of the Special Master on the Arizona Department of Water Resources' Subflow Technical Report, San Pedro River Watershed and Motion for Approval of Report

Procedural Background

In 2001, this Court requested that the Arizona Department of Water Resources ("ADWR" or the "Department") file a report describing how it proposed to determine the extent of stream subflow for purposes of setting the jurisdictional limits of this adjudication. On January 8, 2002, a hearing was held to consider ADWR's "Report Concerning Implementation of the Arizona Supreme Court's Decision on Subflow." On January 22, 2002, the Court directed the Department to prepare more specific and detailed recommendations addressing the following issues arising in the San Pedro River Watershed:

1. A proposal for determining the subflow zone including more than just consideration of the saturated lateral extent of the Holocene alluvium.

2. A test for determining if a well's cone of depression is withdrawing appropriable subflow.

3. A set of rational guidelines for determining whether a given well, though pumping subflow, has a *de minimis* effect on the river system.

4. A method for including both perennial and intermittent streams as part of the subflow analysis, including streams that were historically perennial or intermittent, but are now ephemeral due to development and other human actions.

5. A timeline for completing the tasks outlined in its report.[1]

ADWR's second subflow report was filed on March 29, 2002 (the "Subflow Report"). It specifically addressed each of the requests identified in the January 22, 2002, order. Various parties filed comments and objections to the report, some of which were supported by expert declarations. The Court referred consideration of Subflow Report issues to the Special Master with direction to consider the comments and objections, hold any necessary hearings, and make recommendations as to whether the report should be adopted or modified.[2]

After supervising discovery among the parties, considering expert declarations, and resolving a number of pre-hearing issues, the Special Master held a two-day evidentiary hearing at which the parties and their experts presented their positions on

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[1] Minute Entry ("M. E.") (Jan. 22, 2002).
[2] Order (Feb. 21, 2003).

the procedures proposed in the Subflow Report. Following post-hearing briefing and supplemental oral argument, the Special Master filed his "Report of the Special Master on the Arizona Department of Water Resources' Subflow Technical Report, San Pedro River Watershed; Motion for Approval of Report; and Notice of Subsequent Proceedings" (the "Special Master's Report"), which thoroughly evaluated the Subflow Report, summarized the parties' positions, and set forth the Special Master's recommendations. The Court received additional comments and objections to the report and held a hearing on July 13, 2005, to consider whether it should adopt the Special Master's recommendations and approve or modify the Subflow Report.

The Subflow Zone

This adjudication is charged with determining the rights of all persons to use the waters of the Gila River system and its sources pursuant to A.R.S. § 45-251 *et seq*. This task is complicated by Arizona's bifurcated system of water rights management. While all surface water is subject to this Court's jurisdiction, for decades Arizona courts have protected the rights of groundwater users by holding that surface water appropriation cannot extend to percolating subterranean water. *Maricopa County Mun. Water Conservation Dist. No. 1 v. Southwest*

Cotton Co., 39 Ariz. 65, 4 P.2d 369 (1931), *modified and reh'g. denied*, 39 Ariz. 367, 7 P.2d 254 (1932) ("*Southwest Cotton*").[3]

If setting jurisdictional limits were as simple as declaring that surface water is appropriable while water found underground is not, the adjudication would be much nearer to completing it initial tasks of identifying and prioritizing appropriable water rights. But, although underground water is generally not part of this adjudication, it becomes appropriable if it can be characterized as subflow of a stream. Our Supreme Court has declared that subflow consists of "those waters which slowly find their way through the sand and gravel constituting the bed of the stream, or the lands under or immediately adjacent to the stream, and are themselves a part of the surface stream."[4]

As to how water is to be characterized as subflow, in *Gila II* the Arizona Supreme Court quoted with approval the test first announced in *Southwest Cotton*:

> The best test which can be applied to determine whether underground waters are as a matter of fact and

[3] In lieu of appropriative rights, groundwater users are permitted to withdraw water underlying their land subject only to the doctrine of reasonable use and federal reserved water rights. *In re the General Adjudication of All Rights to Use Water in the Gila River System and Source*, 175 Ariz. 382, 857 P.2d 1236 (1993) ("*Gila II*"); *In re the General Adjudication of All Rights to Use Water in the Gila River System and Source*, 195 Ariz. 411, 989 P.2d. 739 (1999) ("*Gila III*").

[4] *Southwest Cotton,* 39 Ariz. at 96, 4 P.2d at 380. The *Southwest Cotton* court explained that subflow "[i]n almost all cases ... is found within, or immediately adjacent to, the bed of the surface stream.... [and] physically ... constitute[s] a part of the subsurface stream itself, and [is] simply incidental thereto.... It is subject to the same rules of appropriation as the surface stream itself"." *Gila II*, 175 Ariz. at 387, 857 P.2d at 1241 (quoting *Southwest Cotton,* 39 Ariz. at 96-97, 4 P.2d at 380-81).

> law part of the surface stream is that *there cannot be any abstraction of the water of the underflow without abstracting a corresponding amount from the surface stream*, for the reason that the water from the surface stream must necessarily fill the loose, porous material of its bed to the point of complete saturation before there can be any surface flow. (Emphasis in *Gila II*.)
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> . . . .
>
> Not only does [subflow] move along the course of the river, but it percolates from its banks from side to side, and the more abundant the surface water the further will it reach in its percolations on each side. But, considered as strictly a part of the stream, the test is always the same: *Does drawing off the subsurface water tend to diminish appreciably and directly the flow of the surface stream?* If it does, it is subflow, and subject to the same rules of appropriation as the surface stream itself; if it does not, then, although it may originally come from the waters of such stream, it is not, strictly speaking, a part thereof, but is subject to the rules applying to percolating waters.[5] (Emphasis in *Southwest Cotton*.)

In 1987, the judge then assigned to this adjudication, the Honorable Stanley Z. Goodfarb (Retired), issued his first ruling as to which underground waters were to be considered appropriable subflow. The trial judge attempted to craft a practical subflow definition. He held extensive evidentiary hearings that included testimony from hydrologists and

[5] *Gila II*, 175 Ariz. at 388, 857 P.2d at 1242 (quoting *Southwest Cotton*, 39 Ariz. at 96-97, 4 P.2d. at 380-81).

hydrological engineers. He solicited memoranda of law from interested parties and utilized the services of the Department to arrive at a definition he believed would permit the adjudication to move forward. Because a number of parties objected to Judge Goodfarb's subflow determination, the Supreme Court accepted an interlocutory appeal of his order due to "the need to resolve the [subflow] question early in the proceeding."[6]

The Arizona Supreme Court rejected Judge Goodfarb's initial subflow definition and remanded consideration of the issue. It also provided guidance as to how the trial court should undertake to revise its subflow definition by setting forth specific criteria to be used in making this determination:

> Whether a well is pumping subflow does not turn on whether it depletes a stream by some particular amount in a given period of time…. [I]t turns on whether the well is pumping water that is more closely associated with the stream than with the surrounding alluvium…. [C]omparison of such characteristics as elevation, gradient, and perhaps chemical makeup can be made. Flow direction can be an indicator. If the water flows in the same general direction as the stream, it is more likely related to the stream. On the other hand, if it flows toward or away from the stream, it likely is related to the surrounding alluvium.[7]

[6] *Id*. at 386, 1244.

[7] *Id.* at 392, 1246. The specific factors listed in *Gila II* to determine whether water flows constitute subflow are referred hereinafter as the "*Gila II* Criteria".

Upon remand, Judge Goodfarb proceeded to hold additional hearings. He, along with party representatives and experts, traveled within the San Pedro River Watershed to learn about the area's hydrology and geology. After considering additional evidence relating to the relationship of groundwater to surface water, he issued a comprehensive order redefining "subflow."[8] Objections followed, causing the Arizona Supreme Court to expedite consideration of "whether, after remand in *Gila River II*, the trial court properly determined what underground water constitutes 'subflow' of a surface stream, thus making it appropriable under A.R.S. § 45-141(A)."[9]

In *Gila IV*, the Supreme Court approved Judge Goodfarb's second iteration of a subflow description. Twelve years after the Supreme Court's attempt "to resolve the question early," the adjudication court finds itself conducting hearings and considering arguments directed to the question of what is a fair and practical definition of subflow that will permit the Court to define its jurisdictional limits and fairly protect the rights of both surface and groundwater users.

The Subflow Report recommends adopting a number of procedures and assumptions in connection with mapping the subflow zone. Three questions related to these proposals have sparked the most controversy:

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[8] June 30, 1994, Order (the "Goodfarb Order").
[9] *Gila IV*, 198 Ariz. at 333, 9 P.3d at 1072.

- Whether the Court should declare the entire saturated floodplain Holocene alluvium as comprising the limits of the subflow zone without further reference to the criteria announced in ***Gila II***.[10]
- Should the Court assume, for jurisdictional purposes, that the entire floodplain Holocene alluvium is saturated?[11]
- Should the Court adopt the Special Master's recommendation that ADWR's subflow analysis be based upon predevelopment stream flow conditions?

1. Extent of the Subflow Zone

Those objecting to the first recommendation - that the Court find that the saturated floodplain Holocene alluvium is the subflow zone - argue that this proposal permits ADWR to ignore the ***Gila II*** Criteria approved by the Arizona Supreme Court.[12] They rely primarily on two related arguments to support this objection. First, they point to specific language in ***Gila IV*** that purportedly requires continued application of the ***Gila II*** Criteria when mapping subflow limits. They also claim that

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[10] ADWR answered this question affirmatively:

> Upon remand from the Arizona Supreme Court, the trial court engaged in a lengthy hearing process, involving expert testimony on complex hydrogeologic principles, that culminated in a 66-page detailed order with 36 additional pages of exhibits. [citing *Gila IV*] The trial court applied the criteria described in *Gila II* and concluded that the saturated floodplain Holocene alluvium was the 'most credible' subflow zone....

Subflow Report at 2.

[11] ADWR urges adoption of this assumption. *Id*. at 17. ("The Department ... recommends that the entire lateral extent of the floodplain Holocene alluvium be assumed to be saturated for the purpose of delineating the jurisdictional subflow zone.").

[12] *See, e.g.*, Arizona Public Service Company's and Phelps Dodge Corporation's Objections to the Special Master's Report on ADWR's Subflow Technical Report, San Pedro River Watershed (Oct. 1, 2004) ("APS/PD Objection") at 7.

the ***Gila IV*** court did not intend to uphold a trial court ruling that the saturated floodplain Holocene alluvium constitutes the subflow zone. Instead, the Supreme Court simply held that this area comprised the outer limits within which the subflow zone exists. Within this announced area, ADWR is required to apply the ***Gila II*** Criteria to ascertain the subflow zone.[13] These objectors believe that the ***Gila IV*** decision requires ADWR to begin anew and undertake an extensive review of data that might prove relevant in mapping the subflow zone within the San Pedro River Watershed.[14]

As to the latter argument, the question is: In ***Gila IV***, did the Arizona Supreme Court merely direct ADWR as to how and where to commence its inquiry regarding the extent of subflow within the San Pedro River Watershed? Or did the court adopt a standard permitting ADWR to map this Court's jurisdictional limits in an expeditious manner? The Special Master found that "the criteria specified in ***Gila IV*** to delineate the subflow zone have already been taken into account in the Supreme Court's holding that the

[13] *Id*. at 8. ("The fact that the [Arizona Supreme Court] quoted and approved the [*Gila II* Subflow Criteria] does not … support a conclusion that ADWR need not apply the criteria when it delineates the subflow zone. To the contrary, the Court's approval of the criteria makes them binding on ADWR. These criteria *define* the subflow zone, and they *must* be used by ADWR to identify its boundaries.") (Emphasis in original.)
[14] *Id*. at 10. ("ADWR should be instructed to obtain accurate and reliable data for purposes of identifying the subflow zone in *all circumstances*.") (Emphasis in original.)

saturated floodplain Holocene alluvium is the subflow zone."[15] This Court agrees with this conclusion.

The *Gila IV* opinion explicitly recognizes that the trial court considered and applied each of the *Gila II* Criteria in connection with defining how the concept of subflow should be used to set jurisdictional limits:

> [T]he record reflects that the court based its ruling on evaluation of the pertinent factors set forth in *Gila River II* for delineating the subflow zone. For example, the order states:
>
>> After consideration of flow direction, water level elevation, the gradation of water levels over a stream reach, the chemical composition if available, and lack of hydraulic pressure from tributary aquifer and basin fill recharge which is perpendicular to stream and "subflow" direction, the Court finds the most accurate of all the markers is the edge of the saturated floodplain Holocene alluvium.[16]

The Supreme Court noted that, "groundwater users conceded at oral argument, and the record reflects, that sufficient evidence supports the trial court's factual findings, which adopted the saturated floodplain Holocene alluvium as the subflow zone."[17] The objectors cannot overcome the opinion's directive that

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[15] Special Master's Report at 42.
[16] *Gila IV*, 198 Ariz. at 337, 9 P.3d at 1076.
[17] *Id*. at 339, 1078. The Court's footnote reference (n.5) approving the factual finding that the saturated floodplain Holocene alluvium is the subflow zone shows that the trial court's subflow zone definition incorporated the *Gila II* Criteria.

"[t]he entire saturated floodplain Holocene alluvium, as found by DWR, will define the subflow zone in any given area."[18] The opinion makes clear that ADWR is not to generally consider again the *Gila II* Criteria in an effort to undertake again the work that resulted in the trial court's factual findings. To the contrary, the Supreme Court anticipated that mapping the jurisdictional limits of the subflow zone would be relatively simple:

> The record reflects that the saturated floodplain Holocene alluvium is readily identifiable; that DWR can quickly, accurately, and relatively inexpensively determine the edge of that zone; and that some of the work already has been done.[19]

2. Assuming Floodplain Holocene Alluvium Saturation

In mapping the subflow zone, ADWR proposes to assume that the entire extent of the floodplain Holocene alluvium is

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[18] *Id.* at 342, 1081.

[19] *Id.* The objectors claim their position is supported by the fact that in concluding that the subflow zone is comprised of the saturated floodplain Holocene alluvium, the *Gila IV* court also added that ADWR "will determine the specific parameters of that zone in a particular area by evaluating all of the applicable and measurable criteria set forth in the trial court's order and any other relevant factors." *Gila IV,* 198 Ariz. at 344, 9 P.3d at 1083. But *Gila IV* dealt with an order delineating the limits of the subflow zone in the San Pedro River Watershed. The quoted language merely demonstrates the Supreme Court's openness to ADWR considering data, in addition to that found by the trial court, when evaluating other watersheds. *Id.* at 342, 1081. (The entire saturated floodplain Holocene alluvium defines the subflow zone in the San Pedro River Watershed. As to other watersheds, "[i]n the effort to determine [the subflow zone] in other areas, the detailed criteria set forth in the trial court's order, insofar as they apply and are measurable, must be considered, but we do not preclude the consideration of other criteria that are geologically and hydrologically appropriate for the particular location."). As the Special Master's Report recognizes, even within the San Pedro watershed there may be discrete stream segments where ADWR is required to supplement its findings based upon sound and appropriate geological and hydrological principles. Special Master's Report at 42; *see Gila IV,* 198 Ariz. at 342, 9 P.3d at 1081, n.7.

saturated.[20] The Department believes this assumption is required because the two factors determining the extent of saturation - the thickness of the floodplain Holocene alluvium and the depth to the water table beneath the floodplain - are highly variable, both spatially and temporally.[21] Attempts to measure floodplain geology or the depth of the water table at any given point in time are frustrated due to the lack of reliable, contemporaneous data. The Subflow Report states:

> [A]n accurate determination of the saturated portion of the floodplain Holocene alluvium is impractical for three reasons:
>
> - Difficulties in defining the thickness of the floodplain Holocene alluvium;
> - The general lack of detailed and long-term water level data from the floodplain; and
> - The dynamic nature of the floodplain aquifer system.
>
> The Department, therefore, recommends that the entire lateral extent of the floodplain Holocene alluvium be assumed to be saturated for the purpose of delineating the jurisdictional subflow zone.[22]

Some opposing adoption of the Department's saturation assumption stress that:

1. The floodplain Holocene alluvium is not stable. At numerous times, it is not fully saturated; and

[20] Special Master's Report at 52; Subflow Report at 13 & 17.
[21] Subflow Report at 13.
[22] *Id.* at 16-17.

2. The lack of data regarding the extent of saturation within the floodplain Holocene alluvium does not justify adopting an inaccurate assumption.[23]

The Special Master agrees with the objectors and recommends that the Court not approve and adopt ADWR's saturation assumption recommendation. He concluded that ADWR's recommendation does not comport with the directive in ***Gila IV*** "that any test used for determining the boundaries of a subflow zone be as accurate and reliable as possible."[24] Accuracy is paramount because in ***Gila II***, the Supreme Court held that if ADWR uses an appropriate test to delineate the subflow zone, its determination would constitute clear and convincing evidence that a well within the zone is pumping appropriable water.[25] Because saturation fluctuates within the floodplain Holocene alluvium, the Special Master found ADWR's assumption inconsistent with ***Gila IV***.[26] He concluded that the question of whether a segment of the floodplain Holocene alluvium is saturated is only relevant on the date a well is tested:

> The evidence … shows saturation fluctuates even in predevelopment conditions, and a thin upper portion of the floodplain Holocene alluvium is unsaturated.

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[23] *See* ASARCO Incorporated's and Arizona Water Company's Response to Other Parties' Objections to the Report of the Special Master (Nov. 1, 2004) ("ASARCO's Response") at 5-9.
[24] Special Master's Report at 56 (quoting *Gila IV,* 198 Ariz. at 335, 9 P.3d at 1074).
[25] In *Gila IV,* the Court stated, "it is critical that any test used for determining the boundaries of a subflow zone be as accurate and reliable as possible. Otherwise, use of an inaccurate test to determine whether a well is pumping subflow would not satisfy the clear and convincing evidentiary standard…." *Gila IV,* 198 Ariz. at 335, 9 P.3d at 1074; Special Master's Report at 56, n.130.
[26] Special Master's Report at 57.

> To include a well in the adjudication, it is not enough to determine it is highly probable the entire lateral extent of the floodplain Holocene alluvium was saturated at some point. It must be shown it is highly probable the well is pumping subflow from the saturated floodplain Holocene alluvium. (Emphasis supplied.)[27]

Both at the time the trial court issued the Goodfarb Order declaring the lateral extent of the subflow zone, and later when ***Gila IV*** affirmed that order, the dynamic nature of river channels and alluvial basins was well known. The Goodfarb Order reflects that the trial court was fully aware of this characteristic when it was considering subflow issues. The order recites examples of flow changes (***e.g.***, stream channel migration and shifting) that caused the trial court to conclude that river channels are not stable.[28] The trial and appellate courts held that, notwithstanding these variables, the floodplain Holocene alluvium "is the only stable geologic unit which is beneath and adjacent to most rivers and streams … [and] in order to fulfill the definition of 'subflow,' the geologic unit must be saturated because of the need for a hydraulic connection between the stream and the 'subflow'."[29]

Gila IV embodies the Supreme Court's decision that the jurisdictional limits of this adjudication extend to the

[27] *Id*.
[28] Goodfarb Order at 40.

[29] Goodfarb Order at 56; *Gila IV*, 198 Ariz. at 337, 9 P.3d at 1076.

floodplain Holocene alluvium determined at a time of saturation. In upholding the trial court's subflow standard, the Supreme Court quoted with approval the finding that:

> The evidence … shows that the only true geologic unit which is beneath and adjacent to the stream is the floodplain Holocene alluvium. When it is saturated, that part of the unit qualifies as the "subflow zone"….[30]

After more than a decade of dispute, study, and argument, the Arizona Supreme Court provided this adjudication with the following practical (at least with respect to the San Pedro River Watershed) jurisdictional boundary: All surface streams, their sources, and the subflow found within the saturated floodplain Holocene alluvium.

The Goodfarb Order's subflow definition strikes an appropriate balance between surface water and groundwater rights by initially setting the parameters of the subflow zone narrowly.[31] It also employs reasonable assumptions based upon reliable data to include water uses within this limited area in the adjudication. To insure that groundwater users are not unfairly included within the adjudication, our courts have rejected attempts to expand the scope of the subflow zone to

[30] *Gila IV*, 198 Ariz. at 337, 9 P.3d at 1076.
[31] In *Gila IV,* the Supreme Court commented on the trial court's compliance with the direction in *Gila II* that the subflow zone be narrowly construed: "contrary to the groundwater users' argument that the trial court's definition of subflow is broader than *Gila River II* and *Southwest Cotton* permit, the record reflects that saturated floodplain Holocene alluvium occupies only very narrow portions of the alluvial basins." *Gila IV*, 198 Ariz. at 342, 9 P.3d at 1081.

include the entire floodplain alluvium underlying surface waterways and have limited the adjudication's jurisdiction to the Holocene alluvium because it constitutes "the only stable geologic unit which is beneath and adjacent to most rivers and streams…."[32]

It is important to note that determination of the subflow zone does not adversely affect substantive rights of surface or groundwater users. It merely sets parameters with respect to the Court's water use inquiry. As some parties have mentioned, "Arizona is currently in the depths of an extended and severe drought. This drought, a natural and recurring event, has undoubtedly had an effect on the saturated extent of the Holocene alluvium."[33] Should the dynamic nature of a river or stream exclude water users from this Court's jurisdiction who would have been subject to having their rights declared when the proceeding was initiated?[34] While the Special Master and the objectors are correct that the Supreme Court has directed that ADWR and this Court insure that determinations are as accurate

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[32] Goodfarb Order at 56; Special Master's Report at 33.

[33] Arizona Public Service Company's and Phelps Dodge Corporation's Response to Objections to the Special Master's Report on ADWR's Subflow Technical Report, San Pedro River Watershed (Nov. 1, 2004) ("APS/PD Response") at 6-7.

[34] The Apache Tribes correctly point out that Arizona's river systems' dynamic nature, coupled with the fact that ADWR must map various subflow zones in phases, dictates that any temporally limited measurement would be arbitrary. Apache Tribes' Response to the Objections of Certain Parties to the Report of the Special Master on Arizona Department of Water Resources' Subflow Technical Report (Nov. 1, 2004) ("Apache Tribes' Response") at 8-9.

as possible, it also has consistently acknowledged that "subflow" is an "artificial and fluid" term that has purely legal, as opposed to scientific or hydrological relevance.[35] The Supreme Court has made clear that the adjudication court is authorized to adopt reasonable assumptions in order to permit the adjudication to fulfill its functions.[36]

ADWR's saturation assumption is reasonable, practical, and consistent with the goal of permitting this adjudication to be completed "within the lifetime[s] of some of those presently working on the case"[37] (or at least their children's). And the Supreme Court's requirement that subflow be narrowly defined, coupled with the specific recognition that even wells pumping *de minimis* amounts of subflow may be excluded from the

[35] *Gila II*, 175 Ariz. at 392, 857 P.2d at 1246; *Gila IV*, 198 Ariz. at 334, 9 P.3d at 1073.

[36] *Gila IV* explicitly recognized this Court's duty to balance accuracy and expediency in undertaking adjudication tasks when it discussed establishing a test for determining the cone of depression created by withdrawals from a well:

> The [trial] court recognized that each well must be separately evaluated "to compute drawdown at the 'subflow' zone" and that "whatever test ADWR finds is realistically adaptable to the field and whatever method is the least expensive and delay-causing, yet provides a high degree of reliability, should be acceptable."
>
> We agree with the trial court.

Gila IV, 198 Ariz. at 343, 9 P.3d at 1082 (quoting Goodfarb Order at 62).

Likewise, in rejecting the argument that even water claims having a *de minimis* effect on stream flow must be subject to the lengthy adjudication process, the Supreme Court noted, "[p]resumably, Congress expected that water rights adjudications would eventually end. It is sensible to interpret the McCarran Amendment as permitting the trial court to adopt reasonable simplifying assumptions to allow us to finish these proceedings within the lifetime of some of those presently working on the case." *Gila II*, 175 Ariz. at 394, 857 P.2d at 1248.

[37] *Gila II*, 175 Ariz. at 394, 857 P.2d at 1248.

adjudication, ensures that groundwater users' rights will be protected.

3. Use of Predevelopment or Current Conditions

Assuming the floodplain Holocene alluvium is saturated requires adopting a standard not entirely tied to current geological and hydrological conditions. The subflow definition incorporating this assumption uses historical data to prevent hydrological conditions during a specific timeframe from having a disproportionate impact on the adjudication's jurisdictional limits.[38] Some claimants urge the Court to expand on this concept when mapping the subflow zone. They believe that it would be unfair for ADWR to undertake an analysis that determines stream flows based solely upon current conditions. These parties argue that utilizing only current conditions runs the risk of "allow[ing] those who are wrongfully and illegally using appropriable water to continue to do so and would make it more likely that the hydrologic connection between the underground

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[38]ADWR states:

> Due to variations in the depth of the water table, the portion of the floodplain Holocene alluvium that is saturated changes over time, making the determination of the jurisdictional subflow zone difficult. And these variations are not unique to recent times, but apparently also occurred during predevelopment conditions....
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> . . . .
>
> The variety of conditions ... were present ... during both predevelopment and recent times making a determination of the water levels only possible at a particular point in time.

Subflow Report at 15-16.

water and the surface stream is broken."[39] They suggest that using a current conditions methodology will promote disparate treatment between those whose claims are adjudicated earlier vs. later in the adjudication process.[40]

Those objecting to ADWR's use of the alternative to a current conditions methodology - predevelopment stream flow analysis - argue that "predevelopment" is an ambiguous, indeterminate standard, and that there is no accurate, reliable data available to establish appropriate predevelopment conditions.[41] They also point to a portion of the Goodfarb Order's definition of subflow they contend establishes that only current stream flow conditions are relevant.[42]

The Special Master considered whether predevelopment or current conditions data should be used when calculating stream flows. The issue was separately briefed and a provisional ruling issued. After considering additional arguments and evidence, the

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[39] Salt River Project's Response to Objections to Special Master's Subflow Report (Nov. 1, 2004) ("SRP's Response") at 14.

[40] *Id*. at 14-15 ("If the [effective] date is when ADWR performs [its subflow] analysis, each pumper would have [a] substantial incentive to make sure that the watershed in which its well is located would be analyzed as close to the end of these proceedings as possible.") Apache Tribes' Response at 9-10 (It would be unjust "for a claimant to be able to 'pump his way out' of … the jurisdiction of the Court by depleting the subflow zone … in order to create 'current stream conditions' that are ephemeral").

[41] APS/PD Objections at 12; Objections of ASARCO Incorporated and Arizona Water Company to the Report of the Special Master on the Arizona Department of Water Resource's Subflow Technical Report (Oct. 1, 2004) ("ASARCO's Objections") at 8-11; Bella Vista Water Co., Inc., Pueblo Del Sol Water Co. and City of Sierra Vista Objections to the Report of the Special Master on the Arizona Department of Water Resource's Subflow Technical Report (Oct. 1, 2004) ("Bella Vista's Objections") at 4-6.

[42] *See, e.g.*, APS/PD Objections at 18-19.

Special Master expanded on and modified his original determination.[43] His report lists various timeframes targeting periods beginning as early as 1848 to as late as 1978, which some parties suggested as appropriate predevelopment reference points. The Special Master recognized that any period selected "must consider the feasibility of obtaining the requisite technical data and evidence; potential delay and expense of those efforts and of subsequent investigations; level of accuracy and reliability of the subflow analysis; confidence of meeting the clear and convincing evidentiary standard; and fairness."[44] He found that ADWR has not yet had the opportunity to obtain and review maps, reports, and other documents evidencing predevelopment conditions and, therefore, "[i]t is premature to conclude that ADWR cannot obtain reliable evidence of predevelopment stream flow conditions."[45]

In 2002, this Court stated its belief that a proper analysis of subflow required consideration of stream conditions "prior to widespread diversion and depletion of Arizona's stream

[43] The Special Master's Report discusses the claim that both the adjudication and appellate courts have already ruled that current conditions must be used in making subflow zone determinations. After a thorough review of the relevant history of the adjudication, the Special Master properly rejected the argument that "the trial court ruled, and was affirmed by the Supreme Court, that subflow analysis must consider current and not predevelopment stream flow conditions, entitling the affirmed ruling to *stare decisis*." Special Master's Report at 47.
[44] *Id*. at 51.
[45] *Id*. at 50.

flows."[46] The Special Master's Report correctly recognizes that "widespread diversion" does not refer to every activity occurring within a water system. The predevelopment stream flow conditions ADWR considers in its stream flow analysis should be those existing during an identifiable chronological year or range of years immediately prior to regular, discernable diversion or depletion of stream flows resulting from human activity.

The Court agrees with those suggesting ADWR should take a practical approach and adopt the earliest predevelopment timeframe for which accurate and reliable data is available. The Department may find the appropriate predevelopment period differs even within various watersheds due to the quantity and quality of available data. The Department may use its discretion in excluding from its analysis human generated depletions or diversions it concludes were minimal, localized, or sporadic. This approach will ensure the adjudication adopts a jurisdictional standard that assures surface water users that their rights are not prejudiced by the mere passage of time, while recognizing the legal protections supplied groundwater users.

Objectors arguing that the adopted subflow definition restricts stream flow analysis to current conditions rely on the following two guidelines found in the Goodfarb Order:

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[46] M. E. 2, n.1, *supra*.

1. The “subflow” zone must be adjacent and beneath a perennial or intermittent stream.
2. *It may not be adjacent or beneath an ephemeral stream. However, it may be adjacent or beneath an ephemeral section of a perennial or intermittent stream, if the ephemeral section is caused by adjacent surface water diversion or groundwater pumping.* There must, however, be a saturated zone beneath connected to similar zones beneath the upper and lower perennial or intermittent stream sections. (Emphasis supplied.)[47]

Some parties refer to the italicized language above as the “ephemeral stream exception.”

Those urging use of current conditions assert that the “ephemeral stream exception language demonstrates that the trial judge intended that the subflow exception be adjudicated under current and not predevelopment conditions because no groundwater pumping or surface water diversion existed” in the predevelopment era.[48] They believe that any proposed definition of “predevelopment” is automatically at odds with the ephemeral stream exception because the diversions and depletions mentioned in the exception could not have occurred in a predevelopment period.[49]

[47] Goodfarb Order at 35.
[48] Cities’ [of Chandler, Glendale, Mesa, and Scottsdale] Response to Comments and Objections to Special Master’s Subflow Report on the Arizona Department of Water Resources’ Subflow Technical Report (Nov. 1, 2004) (“Cities’ Response”) at 5.

[49] APS/PD Objections at 19.

Although finding that no court has resolved the predevelopment or current conditions dispute, the Special Master found "that in order to give effect to the plain language of the exception, and incorporate it into the subflow analysis, the applicability of the ephemeral stream exception must be determined using post-development conditions."[50] This Court believes that when read in proper context, the ephemeral stream exception supports use of predevelopment conditions to delineate the subflow zone.

At its core, the Goodfarb Order provides that the subflow zone may only be comprised of areas related to perennial and intermittent streams. That is the rule. No ephemeral streams may be included. The exception to this rule arises when evaluating streams that would legitimately be categorized as ephemeral, but only because of the effect of surface water diversions or groundwater pumping. The exception requires, in effect, that these streams be considered in a predevelopment state. That is, if one assumes away the effects of diversions and pumping, would the subject streams share the characteristics of an adjacent intermittent or perennial stream? If the answer is "yes," they can be included within the subflow zone due to their predevelopment attributes. Instead of an admonition to use only current conditions, the ephemeral stream exception is evidence that the Goodfarb Order contemplated that ADWR would outline the

[50] Special Master's Report at 47.

subflow zone without having to be concerned that human generated water diversions or depletions might artificially divest jurisdiction over water right claims this Court is charged with adjudicating.

The remainder of the Special Master's recommendations concerning subflow analysis, namely Recommendation Nos. 1 through 10, 18, and 19, provide guidance as to how ADWR should map the subflow zone and are less controversial than those discussed above. The parties and this Court generally agree that the Department should incorporate the definitions of "perennial, intermittent and ephemeral streams" announced in the Goodfarb Order, consider a wide variety of resources (*e.g.*, historical data, scientific reports, aerial photography, and field studies) when attempting to locate all the streams within a watershed, and take special care to ensure that the mapping methods used are as accurate as possible.[51]

The Cone of Depression Test

In *Gila IV*, the Arizona Supreme Court held that the rights to withdraw water from some wells located outside of the jurisdictional subflow zone are to be adjudicated by this Court. The included wells are those:

[51] *Id*. at 24-39. In approving the Special Master's Report Recommendation No. 6, which provides that "[t]he Court should direct ADWR to exclude from the subflow analysis the ephemeral streams shown in the NRCS soils survey maps," the Court does not intend to modify its ruling as to how ADWR is to apply the ephemeral stream exception when mapping the subflow zone.

> [L]ocated outside the lateral parameters of the defined ‘subflow’ zone … [whose] ‘cones of depression’ reach the ‘subflow’ zone and the drawdown from the well affects the volume of surface and ‘subflow’ in such an appreciable amount that is capable of measurement…. [A] well may be subject to the adjudication if its ‘cone of depression’ caused by its pumping has now extended to a point where it reaches an adjacent ‘subflow’ zone, and by continual pumping will cause a loss of such ‘subflow’ as to affect the quantity of the stream.[52]

In response to this Court’s request, ADWR devised a method for determining whether water pumped from a well located outside the subflow zone creates a cone of depression that intercepts and withdraws subflow. The second series of issues discussed in the Special Master’s Report address the recommendations for implementing the Department’s proposals for measuring cones of depression created by well pumping.

[52] *Gila IV*, 198 Ariz. 342-43, 9 P.3d 1081-82.

1. Testing Standards and Techniques

ADWR proposes an eleven-step cone of depression test.[53] The Department recommends that determinations should be made on a well-by-well basis, but that some components of its test should be combined to permit more efficient collection of data relating to wells located within a general area. To increase efficiency and reliability, the Department desires to use analytical and numerical models as part of its testing process. The Special Master's Report describes these models as "sets of mathematical flow equations whose solutions yield simulations of the behavior of aquifers in response to stresses."[54] Use of models is intended to provide ADWR with a simplified representation of an aquifer based upon available hydrogeologic information concerning local conditions and aquifer properties. When mapping the subflow zone in an area comprised of simple geology, ADWR proposes to use an

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[53] The Department will:

1. Determine well location, elevation, and distance from jurisdictional subflow zone;
2. Determine pumping history;
3. Determine frequency of pumping;
4. Determine how the well was constructed;
5. Characterize local hydrogeologic conditions;
6. Define local aquifer properties;
7. Construct a conceptual model of the aquifer system;
8. Select a mathematical model;
9. Input data and run a simulation using mathematical model;
10. Analyze model output; and
11. Determine whether a well should be adjudicated.

Subflow Report at 23.

[54] Special Master's Report at 74

analytical computer program to determine a well's cone of depression. When confronted with areas in which an aquifer is more complex, the Department will shift to a numerical model, the use of which is more time consuming and requires supplemental field data for proper calibration.

In order for a well to be included in the adjudication, ADWR suggests that two conditions must be met as of the time of the modeling:

1. The well's "simulated cone of depression has reached the edge of the jurisdictional subflow zone and drawdown at that point is greater than or equal to 0.1 foot;" and

2. The "water level in the well is *below* the water level in the jurisdictional subflow zone during pumping… " (Emphasis in Subflow Report.)[55]

Criticism of the 0.1 foot standard focuses on the claim that ADWR's computer models cannot provide consistently accurate measurements of the extent of drawdown at the edge of the subflow zone.[56] Objectors concede it is possible to obtain accurate water level measurements at 0.1 foot increments, but argue these results cannot be acquired solely by using the

[55] Subflow Report at 31.
[56] One claimant asserts that the Goodfarb Order held that the 0.1 foot criterion couldn't be used. ASARCO's Objections at 13. The Court agrees with the Special Master that the trial court's belief in 1994 that drawdown measurements at 0.1 foot increments would be "difficult" proved to be incorrect and, in any event, does not serve as an impediment to adopting an appropriate method for evaluating a cone of depression. Special Master's Report at 63.

models endorsed by the Department.[57] They claim that absent field test corroboration, ADWR's use of computer modeled simulated water levels will fail to satisfy the requisites for cone of depression measurements announced in ***Gila IV***.

The Special Master carefully considered arguments for and against ADWR's proposal and concluded:

> ***Gila IV*** requires that the cone of depression test must yield results with a high degree of reliability. Under the clear and convincing evidentiary standard, ADWR's determination that a well's cone of depression impacts the subflow zone means it is highly probable the cone of depression has reached the edge of the subflow zone. The Special Master finds that a computer model's simulation of a greater than or equal to 0.1 foot drawdown can satisfy the degree of reliability required by ***Gila IV*** and the highly probable standard of clear and convincing evidence. The requisite reliability will depend … on the quality and quantity of parameter inputs. A focused and reasonable effort to collect and use reliable data and information must be made if a high degree of reliability is to be attained.[58]

In evaluating the Department's proposed cone of depression test, the Court must keep in mind both that absolute accurate quantification is not possible, and a hodgepodge system of uncertain reliability is not acceptable. Even though some requisite data for accurate cone of depression measurements

[57] BHP Copper Inc.'s Objection to Report of the Special Master on the Arizona Department of Water Resources' Subflow Technical Report, San Pedro Watershed (Oct. 1, 2004) ("BHP's Objection") at 5-9; APS/PD Objection at 22-27.
[58] Special Master's Report at 65.

"will often be either unknown or poorly known,"[59] ADWR is charged with adopting a test that is "realistically adaptable to the field" and measurement standards that are "the least expensive and delay-causing" efficient methods that provide "a high degree of reliability."[60] In judging whether the Department has satisfied these directions, the Court accepts that "[c]onducting cone of depression tests requires numerous assumptions and considerable judgment and, in many cases, the test results will only provide a rough approximation of actual field conditions."[61]

ADWR's modeling proposal, as clarified by the Special Master's Report, is an affordable, delay-avoiding, adaptable method of determining cones of depression that provides an acceptable degree of reliability and accuracy. The parties agree that the 0.1 foot drawdown criterion comports with the "appreciable" and "measurable" standards put in place as a result of the decisions in *Southwest Cotton* and *Gila II*. The only legitimate concern is whether computer models can accurately reflect a well's drawdown.

At the hearing held on this issue, testifying experts uniformly acknowledged that they "use analytical and numerical computer models to estimate drawdown to 0.1 foot (or smaller) and that they report such results to their clients with the

[59] Subflow Report at 21.
[60] *Gila IV*, 198 Ariz. at 343, 9 P.3d at 1083.
[61] Subflow Report at 21-22.

expectation that the clients will rely upon those results."[62] While this observation is not determinative, it is instructive as to how those in the industry regard the use of modeling. More important, the evidence before the Special Master established that any error potential can be dramatically reduced by paying close attention to the accuracy of the data relied upon when setting the parameters used by the computer models. The Special Master's recommendation with respect to cone of depression measurements addresses the objectors' concerns by making clear that ADWR's proposed methods will satisfy the requirements of ***Gila IV*** and the "highly probable" clear and convincing evidentiary standard only if the Department implements a focused and reasonable mechanism for obtaining highly reliable data which are used in setting model parameters.[63]

ADWR's second condition for including a well within the adjudication is that the well's water level is below the water level in the jurisdictional subflow zone during pumping. The Department believes that a well should not be included in the adjudication if it is not located within a topographic area conducive to causing water to flow from the subflow zone to the well. Under this definition, subflow drawdown potential would be

[62] SRP's Response at 22; *see* Special Master's Report at 61.
[63] Special Master's Report at 65. The Court also agrees with the Special Master's rejection of the alternative methods suggested for determining a well's cone of depression because due to inaccuracy, cost, problems with implementation, and delay, they do not satisfy the economy, expediency, and reliability criteria set forth in *Gila IV*. *Id*. at 68 & 70-71.

determined based upon the hydraulic gradient between a stream and a well.[64] Making these determinations regarding the nearly 6,500 wells in the San Pedro River Watershed would be costly and potentially delay subflow zone determination for some time. The Special Master concluded this process was neither feasible nor practical and would not comply with ***Gila IV's*** economy and expediency criteria.[65]

The Special Master also noted that tying a well's inclusion in this adjudication to hydraulic gradient reversal is not consistent with the following findings made in the Goodfarb Order:

> [S]tream depletion occurs as soon as the "cone of depression" reaches the stream, even though it may be some time before the hydraulic gradient at the river is reversed, and may be many years before a particle travels from the stream to the well. (Citation to transcript omitted). [Expert witnesses] Ford and Page contend that streamflow depletion first takes place when the cone intersects the stream, not when the hydraulic gradient is reversed or the molecule of streamflow is ejected by the well. (Citations to transcript omitted). It is beyond dispute that even before the gradient is reversed, a measurable drawdown at the stream's "subflow" zone necessarily results in water leaving the zone in order to fill the void which has been created by the well. Ford's Report, (citation omitted) [when the cone intersects the "subflow" zone,

[64] Under this test, ADWR would determine if there was hydraulic gradient reversal over the entire distance between a well and a stream. That is, does the gradient flow downward continuously from the stream to the well? *Id*. at 70.
[65] *See* n.64, *supra*.

> it "induce[s] subflow to leave (deplete the Subflow Zone and the stream")]. <u>This is true even where the gradient has not been reversed everywhere between the well and the stream.</u> (Emphasis by Special Master.)[66]

The ***Gila IV*** court's affirmance of the Goodfarb Order, which included the language quoted above, mandates that it is the effect on a stream and its subflow, not additions to a well's output, that is to be measured when deciding which wells are subject to this Court's jurisdiction.

2. Transient or Steady State Modeling

Having approved the use of analytical and numerical computer modeling, the Court must address the temporal parameters to be used when testing. ADWR suggests that only the time of modeling be considered when applying the cone of depression test. This test method is called "transient state modeling." Its major deficiency is that it is a snapshot approach that does not account for the fact that a well's cone of depression is dynamic. The parties agree that a well's cone of depression generally stabilizes gradually, expanding or decreasing after the period of modeling. Transient state models do not account for the prospective impact of well withdrawals. This testing approach may result in wells that will impact the subflow zone for only the briefest portion of the next millennium being included in the adjudication, while other wells

[66] Special Master's Report at 73 (quoting Goodfarb Order at 61).

that will have a dramatic impact on the subflow zone (but not during the relatively short modeling period) are not included.

Those criticizing ADWR’s proposed approach urge the Court to direct the Department to use a steady state model.[67] While no one can predict with certainty the future use of wells, the steady state model does not have a temporal limit and purports to account for the future impact of withdrawals by using long-term average hydrologic data to establish an equilibrium between a pumping well and the amount of water the well withdraws from streams and underground sources.[68] The weakness of steady state modeling is that it does not as accurately account for conditions during a specific time period and, according to its critics, cannot effectively simulate either the dynamic hydrologic systems in Southwestern deserts or changes in groundwater storage.[69]

It is clear that if a more accurate result is desired with respect to a relatively narrow timeframe, transient state modeling is preferable, but if long-term accuracy is needed, the steady state model will, over time, be more useful. Which approach is more appropriate for the adjudication?

The Special Master resolved this issue by focusing on the following excerpt from *Gila IV*:

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[67] Special Master’s Report at 82.
[68] *Id*.
[69] *Id*. at 83.

> [A] well may be subject to the adjudication if its " 'cone of depression' caused by its pumping has now extended to a point where it reaches an adjacent 'subflow' zone, and by continual pumping will cause a loss of such 'subflow' as to affect the quantity of the stream."
>
> … DWR may seek to establish that a well located outside the limits of the saturated floodplain alluvium is in fact pumping subflow and is therefore subject to the adjudication, by showing that the well's cone of depression extends into the subflow zone and is depleting the stream. (Emphasis by Special Master.)[70]

Relying on the language above, the Special Master concluded that the steady state model's attempt to consider the future impact of a well's cone of depression does not comport with the requirements announced in ***Gila IV*** because to be included within this Court's jurisdiction, a well's cone of depression must extend into the subflow zone, and the well must be ***currently*** depleting a stream.[71] Review of relevant sections of the Goodfarb Order and the ***Gila IV*** opinion cause this Court to reach a contrary conclusion.

After narrowly defining the area in which subflow may be found, the Arizona Supreme Court adopted a more expansive standard with respect to who, within this narrow zone, is

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[70] *Id*. (quoting *Gila IV*, 198 Ariz. at 343, 9 P.3d at 1082).
[71] Even though he viewed ADWR's transient state modeling proposal favorably, the Special Master was apparently uncomfortable with the potential unjust results that can flow from snapshot measurements. *Id*. at 84 ("Although *Gila IV* and the evidence do not support rejecting ADWR's recommendation, the impact of expanding cones of depression must be taken into account.").

subject to the adjudication.[72] Adopting the reasonable assumptions made in steady state modeling is consistent with the principles announced in the Goodfarb Order and approved by the ***Gila IV*** court. The Goodfarb Order explicitly recognized that cones of depression expand over time and can have a long-term effect on subflow even after well pumping ceases:

> [The] facts show … that "cones of depression" have long-term effects even after the wells are shut down. Two recent Colorado cases make that clear. Danielson v. Castle Meadows, 791 P.2d 1106 (Colo. 1990) and State Engineer v. Castle 6 Meadows, 856 P.2d 406 (Colo. 1993) discuss the long-term effect of post-pumping depletion. In the "Danielson" case the trial court had found that post-pumping depletions could continue up to and after 200 years. In the remanded trial which took place in 1991, the trial court found the post-pumping depletions could continue up to and after 400 years. In both cases the Colorado Supreme Court found that these post-pumping depletions had to be remedied by the pumps to protect surface water users….
>
> All of the principal witnesses agreed that even wells located outside of a stream's "subflow" could, over time, build up extensive "cones of depression" which could severely affect the volume of stream flow and the "subflow" which supported it.[73]

The trial court's finding that "stream depletion occurs as soon as the 'cone of depression' reaches the stream, even though it may be some time before the hydraulic gradient at the river

[72] *Gila IV*, 198 Ariz. at 343, 9 P.3d at 1082.
[73] Goodfarb Order at 60.

is reversed, and may be many years before a particle travels from the stream to the well" evidences that the court intended for future pumping consequences to be considered when setting the adjudication court's jurisdiction.[74] When this ruling is read in conjunction with the quote from *Gila IV* relied upon by the Special Master, an alternative interpretation appears:

> [A] well may be subject to the adjudication if its " 'cone of depression' caused by its pumping <u>has now extended to a point where it reaches an adjacent 'subflow' zone</u>, and <u>by continual pumping will cause</u> a loss of such 'subflow' as to affect the quantity of the stream." (Emphasis supplied.)

The language cited above is consistent with the Goodfarb Order and requires that a well with a cone of depression reaching the subflow zone be subject to adjudication if the extent of the well's current or prospective depletive effect on the stream is measurable by reasonably accurate means. Only steady state modeling adequately addresses the need to consider the future consequences of existing well characteristics that was contemplated by the Goodfarb Order.

3. Cumulative Effect of Multiple Well Drawdowns

The *Gila IV* opinion requires that wells must be individually evaluated to determine if they are subject to the adjudication. The Special Master's Report asks whether, in

[74] *Id*. at 61.

addition to this individual analysis, the cumulative drawdown effect of groups of wells should be reviewed.[75] Parties favoring cumulative testing claim that available numerical models easily and accurately calculate the cumulative impact of clusters of wells.[76] They argue that the Court must direct ADWR to undertake individual and cumulative analysis in order to adequately protect surface water rights. Other parties argue that cumulative testing will detract from the Department's efforts to complete higher priority tasks directly related to statutorily mandated tasks.[77] The Special Master's Report adopts a hybrid position and recommends that ADWR select one or more groups of wells to test whether cumulative analysis is warranted.

Because the jurisdictional limits of the subflow zone are strictly drawn, the better approach is to undertake such analysis as is required to identify all wells within this narrow region that are affecting subflow. The Special Master's Report indicates that an anticipated hydrological study of the Sierra Vista Subwatershed may provide additional relevant information regarding the individual and cumulative effects of well

[75] Special Master's Report at 86.
[76] Apache Tribes' Objections to the Report of the Special Master on Arizona Department of Water Resources' Subflow Technical Report (Oct. 1, 2004) ("Apache Tribes' Objections") at 21-22; United States' Response to Exceptions to the Report of the Special Master on the Arizona Department of Water Resources' Subflow Technical Report, San Pedro River Watershed (Nov. 1, 2004) ("U.S. Response") at 14-15.
[77] ASARCO Incorporated's and Arizona Water Company's Reply in Support of Objections to the Report of the Special Master on the Arizona Department of Water Resources' Subflow Technical Report, San Pedro River Watershed (Dec. 1, 2004) ("ASARCO's Reply") at 9.

pumping.[78] At least with respect to the San Pedro watershed, the Department should ascertain whether significant withdrawals of subflow occur as the result of pumping by one well or a group of wells.

De Minimis Uses

With one limitation, the *Gila IV* decision requires wells located within the lateral limits of a subflow zone to be subject to this adjudication. The exception excuses those wells "that, though pumping subflow, have a de minimis effect on the river system…. [Those wells] may be excluded from the adjudication based on rational guidelines for such an exclusion, as proposed by DWR and adopted by the trial court."[79] *Gila II* also sanctions summary adjudication of *de minimis* water rights.[80]

The Subflow Report describes the work done by then Special Master John Thorson to determine if certain stockwatering, stockponds, or domestic water uses in the San Pedro River Watershed qualified for summary adjudication. Special Master Thorson concluded that when measured individually these uses had a *de minimis* impact on the watershed, and even though their cumulative impact was not *de minimis*, he found that the resources required to individually adjudicate and administratively manage these water rights justified summary

[78] Special Master's Report at 88.
[79] *Gila IV*, 198 Ariz. at 344, 9 P.3d at 1083.
[80] *Gila II*, 175 Ariz. at 394, 857 P.2d at 1248.

adjudication. ADWR accepted the Special Master's definitions of what constitutes a *de minimis* domestic, stockpond, or stockwatering use, but the Department did not agree with the Special Master that these uses should be adjudicated summarily. Because the Subflow Report was filed on March 29, 2002, the Department's discussion did not reflect that on September 26, 2002, this Court approved Special Master Thorson's proposed *de minimis* definitions and adopted his recommended summary adjudication procedures.[81]

Some claimants suggest that the Court direct ADWR to propose guidelines for determining when non-domestic water uses (*e.g.*, agricultural, municipal, industrial, and other uses) have a *de minimis* effect on a watershed.[82] They believe the Department should propose a set of *de minimis* criteria that apply irrespective of the type of water use.[83] The Court agrees with these parties that a prime consideration when determining if a water use has a *de minimis* effect on a watershed is its quantifiable impact on the subflow zone. Until ADWR proposes an accurate and reliable method for determining quantifiable impacts, its *de minimis* proposal will be deficient."[84]

The Special Master's Report and some comments indicate that the parties did not extensively brief this issue, and it may

[81] Memo. Dec. (Sept. 26, 2002).
[82] Special Master's Report at 93.
[83] APS/PD Objections at 37.
[84] *Id*.

"best be considered at such time as ADWR and the parties have more new or updated data."[85] The Special Master will be directed to seek input from the Department and claimants, and conduct such proceedings as he deems necessary to craft a workable, reasonably accurate *de minimis* standard that can be applied to non-domestic water users.

Implementation of Procedures

The Department and the Special Master have supplied a number of recommendations responding to the Court's request that ADWR propose a schedule for completing the tasks outlined in its report. The Court agrees with the Special Master that ADWR's proposal of first mapping the subflow zone in a watershed, then identifying *de minimis* uses, and finally conducting cone of depression tests is appropriate.[86] The parties generally agree with this plan, although some disagree with the Special Master's recommendation of a period of one hundred twenty (120) days for filing objections to ADWR's technical report delineating the subflow zone.[87] The Court does not challenge the Special Master's analysis of the applicable statutory authority governing the filing of objections, but it will accommodate the desire of claimants requesting a one hundred eighty (180) day period for the timely filing of objections and comments to a technical

[85] Special Master's Report at 93; *see* SRP's Response at 36-37.
[86] Subflow Report at 45; Special Master's Report at 96.
[87] APS/PD Objections at 38-39.

report. The Court agrees with the remainder of the Special Master's recommendations regarding the implementation of procedures.

The foregoing discussion constitutes the Court's findings of fact and conclusions of law with respect to the Special Master's Report and the Department's Subflow Report. Based upon these findings and conclusions,

IT IS ORDERED, approving the Subflow Report as modified by this Order.

IT IS FURTHER ORDERED, that with respect to the recommendations set forth in the Special Master's Report:

1. The Court approves and adopts, as modifications to the Subflow Report, Recommendation Nos. 1, 2, 3, 4, 5, 7, 8, 9, 10,11 ,13, 14, 20, 21, 22, 23, 24, 25, 26, 27, 30, and 31.
2. With respect to Recommendation No. 6, the Court approves and adopts this recommendation, but notes that ADWR shall include as part of the subflow zone any areas determined to fall within the ephemeral stream exception discussed above.
3. If ADWR determines, with respect to any specific area, it cannot delineate a reasonably accurate and reliable subflow zone, it shall proceed in accordance with Recommendation No. 12.

4. Recommendation No. 15, as clarified by this Order, is approved and adopted.
5. Recommendation Nos. 16, 17, and 32 are not approved and adopted.
6. Recommendations Nos. 18, 19, 29, 33, 34, 36, 37, 38, and 39 are approved and adopted to the extent consistent with this Order.
7. Recommendation No. 28 is not approved and adopted. ADWR shall utilize a reasonably reliable steady state model for use in evaluating the effect of cones of depression.
8. The Court approves and adopts Special Master's Recommendation No. 35 to the extent modified by this Court's holdings.
9. The Special Master is directed to seek input from the Department and claimants and take such other necessary steps to fashion standards for identifying non-domestic *de minimis* water uses.

IT IS FURTHER ORDERED, that claimants shall be provided a period of one hundred eighty (180) days from the filing date to file timely objections and comments to technical reports containing ADWR's subflow zone determinations.

DATED: September 28, 2005.

/s/ Eddward P. Ballinger, Jr.
EDDWARD P. BALLINGER, JR.
Judge of the Superior Court

* * * *

A copy of this minute entry is mailed to all parties on the Court-approved W-1, W-2, W-3 and W-4 mailing list dated June 15, 2005, and the parties listed below.

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IN THE SUPERIOR COURT OF THE STATE OF ARIZONA

IN AND FOR THE COUNTY OF MARICOPA

W-1, W-2, W-3, W-4 (Consolidated) Contested Case No. W1-103	)
In Re the General Adjudication of All Rights to Use Water in the Gila River System and Source	)
In Re: Evidentiary Hearing Day 3	)

BEFORE THE HONORABLE EDDWARD BALLINGER, JR.

Phoenix, Arizona
January 26, 2012

EXCERPTED TRANSCRIPT OF PROCEEDINGS

REPORTED BY

KIM J. HANNAN, RPR,RMR
Official Reporter
Certificate No. 50494

A P P E A R A N C E S

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For the Gila River Indian Community:	THOMAS L. MURPHY Attorney at Law
For the San Carlos Apache Tribe and Tonto Apache Tribe:	JOE P. SPARKS Attorney at Law
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For the Nature Conservancy:	STEPHEN C. CANN Attorney at Law

P R O C E E D I N G S

THE COURT: You know, maybe I should give you some help. I know how I'm going to rule. I assume evidence is closed; right? There's no more evidence to be submitted?

MR. LEMASTER: No, Your Honor.

THE COURT: It seems to me that the conclusions to be reached, based upon the presentations here, are not difficult. I mean, the work's been difficult, but figuring out where that brings us is not difficult, so all I can tell you that is when I look at these objections, for you and I to spend five minutes arguing about it, okay, it's in. It doesn't convince me, but okay, it's in.

I know what I distilled from Mr. Ford's work and from Miss Uhlmann's work and from the others, and it really didn't -- didn't -- I was surprised by the extent of the consensus.

MR. LEMASTER: All right.

Then -- then I don't want to spend time, because if you want us to do conclusions and --

THE COURT: Well, I want to try and give you some guidance for that. In other words, I want to tell you -- there's no reason for you to -- or anybody to do a -- a set of conclusions that assumes that the Department's report has been approved in its entirety, because that's not going to happen. And there's no reason to assume that all the objections have been granted, because that's not going to happen. So I wanted to go over that I make sure I address your issues unless -- first I want to make sure does anyone disagree the evidence is now closed?

No. Okay. So now I feel more free to talk about what I want to talk about.

So did you have anything else?

Let me hear what they have to say.

MR. LEMASTER: I think the only other issue -- excuse me, Your Honor -- we're going to talk about how to deal with some of the exhibits, but maybe --

MR. McGINNIS: I have a question on what you just said.

THE COURT: Yeah.

MR. McGINNIS: I'm trying to figure out whether you said okay, it's in, and that it doesn't matter whether it's in or not.

THE COURT: I'm going to tell -- I'm going to take back my -- I'm going to let the Uhlmann affidavit declaration in its entirety. It's just the easiest way to make a clean record, because I think when I talk to you in a second, everybody's going to know what I concluded and why -- I don't want to create issues on appeal. And nothing with respect to comments by Miss Uhlmann concerning critiques or -- or her views of the work of others affected me in the slightest. That doesn't mean I discounted her conclusions. I'm just saying her comments on, for example, Mr. Ford, I didn't give much weight.

MR. McGINNIS: Understand that.

The other question, and I don't know whether you want to do this next or not, is the exhibits.

THE COURT: I think it would be a good idea for us to do that now.

MR. McGINNIS: Do that now?

At the beginning you said we -- we had worked out what we -- our objections, both sides, and you had said you only want those admitted that we actually used.

THE COURT: Well, you referred to a lot of materials.

Absolutely everything that was used or referred to, since all objections were waived, I have no problem trying to help you all make a record that those things were all admitted. I think that's what everybody agreed to; right?

MR. McGINNIS: Right. And the question becomes --

THE COURT: How do we delineate those?

MR. McGINNIS: Yeah. There are things that were -- were cited in the affidavits, which I think from my question on Tuesday you said that's okay.

THE COURT: Yes.

MR. McGINNIS: Things that were used -- used this week, I'm not sure we all tracked whenever Exhibit 46 was mentioned.

THE COURT: Well, since I know -- the lucky thing is that based upon we -- there's -- I don't think there's any exhibit that anybody can enumerate now that they wanted to use that they didn't get to use.

MR. McGINNIS: I think that's true.

THE COURT: And so really, all that has to happen is between now and sometime, we all have to -- that means you -- have to come up with a list of what all those are, but I don't anticipate there's any disagreement. Someone may say you may give a list, you may present a list, and you'd say, "You forgot two of 'em," and all you have to do is say, "You're right. Those were used." They're in.

MR. McGINNIS: And that's, I think, what Mr. Lemaster and I were going to suggest is that we do that, submit a list to you. We'd like to have until after we get --

THE COURT: Yes.

MR. McGINNIS: -- the transcript.

THE COURT: Yeah.

I just think that's good, otherwise you're going to get two lists because you'll forget something. But, yeah, I don't -- I think everyone agrees, and let's make a record of it, that there's not going to be an objection to anything identified in the record, that was used during the hearing, being deemed part of the record.

MR. McGINNIS: That -- that's -- I think that's they way to do it.

The other -- the other question I had about a specific exhibit is I had one that was a blowup map, that had the sheet on top of it, that we drew wells on. That was -- that was something we created as a demonstrative exhibit at the end. It's not in the pretrial statement. I think would be helpful for the Court to have it in the record. I tried really hard to describe where I was drawing with the map, drawing on the circles.

THE COURT: If you object, I'm not going to let it in. Do you care?

MR. LEMASTER: I don't care, Your Honor.

MR. McGINNIS: I just thought it would be helpful for somebody to have.

THE COURT: I don't disagree, but it's demonstrative, so it could be a valid objection, but since there's no objection, it can come in.

MR. McGINNIS: Okay. Thank you.

Judge, I think that's all we had. And other than coming up with a date for a --

THE COURT: Well, let's -- okay. Let's talk about that.

MR. McGINNIS: Not post summary -- findings and conclusions.

THE COURT: I want to visit with the Department.

Well, I asked -- I took the liberty of asking both the person that currently speaks for the Department, at least technically, Mr. Johnson and author of the -- main author of the two reports, Mr. Burtell, their views on certain things, but I want to ask you as one that speaks for the Department.

When I look at whats happened here today, I come away with a belief that the Department's position is that they accurately responded to the instructions they were given and created a map that does identify floodplain Holocene alluvium and nothing other than floodplain Holocene alluvium, but that the Department, in reviewing comments by other subsequent to the work that was originally done, agrees with a couple of thing. One, the current map submitted by the Department does not accurately identify all the floodplain Holocene alluvium; is that true?

MS. RONALD: That's correct, Your Honor.

THE COURT: And that the Department has no objection to saying, "Okay. Let's try and figure out where we should go from here to make sure that we can identify more of it."

MS. RONALD: Correct.

THE COURT: Okay. So, that means I agree with that, and that means that by definition, the ruling that I'm going to have to make sustains -- denies in part the objections made and sustains them in part consistent with what we're going to talk about now.

The -- let me put a couple things on the record and I'll get back to you.

The evidence clearly shows and requires that the Court overrule in part, sustain in part the ADWR -- ADWR's 2000 -- June, 2009 subflow zone delineation report for the San Pedro watershed. The Department has -- has successfully prepared what exists as a skeleton of what will finally become the delineation of the full extent of the San Pedro subflow -- the subflow zone of the San Pedro watershed. But the evidence also clearly establishes that the current ADR delineation does not accurately reflect the full extent of subflow in this watershed. That may be due to ambiguous or perhaps not completely helpful directions from every judicial officer except me.

And the other -- the other thing that we've got to talk about is the evidence, although it establishes a number of things that might be helpful, it does not -- it does not show a clear, specific prescription of exactly what should -- ADWR should be told to do in every instance, except that it shows that the next iteration of the map should have certain characteristics, and those include a subflow zone that must be continuous. It has to be a continuous subflow zone. And it also, number two, has to identify to a great extent of reasonable certainty the entire amount of floodplain Holocene alluvium. And where possible, it must interpret judicial pronouncements so as to -- in a manner consistent with scientific fact.

Specifically, I believe that the intention of prior pronouncements by Judge Goodfarb and the Arizona Supreme Court with respect to setbacks were intended to give guidance of how to have a feasible, easy to use, a general rule to delineate the extent of hydrologic connection when one exists, but were not -- but was not intended to say that if it's clear to everyone -- and to me there's testimony by every expert in this hearing that there have been instances where setbacks have used when there's no scientific fact to base there being any hydrologic connection between ephemeral alluvium and what could be defined as a subflow zone. What I think it's designed to do is to have in the next iteration of what ADWR -- next version of what ADWR does is to give them a number of options of various modalities can be used, but not with the direction that you have to use each modality at every spot along the subflow zone. You should -- the Department should be able to use its judgment to have a justifiably supported interpretation of what modality should be used and when.

I also find that the evidence establishes that all of the experts believe that the extent of the subflow zone, although needing to consider subsurface conditions, does not require drilling, and that no one here has suggested -- I've reviewed the position papers of the groundwater users and the surface -- surface users, none of them suggest that the Department undertake the very expensive and lengthy process of doing a number of actual subsurface drilling activities or other things like that.

Any questions about that?

How many hundreds of questions do you have about that?

What I want to do is, and I'm inviting you to do this when you submit your -- your findings of fact proposed, I want you to think about, I'm going to put on the table how you might start this second iteration. What I'd like to do is to have something that I can tell people, "Okay. I've looked at this. This makes reasonable sense."

No matter what you do and no matter what you produce, there will be objections, we all know that. But I want to put it in a place where we've all talked about those reasonable assumptions the Department made. You're going to have to make subjective determinations based upon the best judgments of those doing the work. The fact that there could be two different experts that might have a different view doesn't mean that the one that's proposed is wrong. It just means that this is -- this is a defensible subflow map. That's what I want to try and work for.

Does that make sense?

MS. RONALD: It does make sense. And we've had quite a number of conversations about exactly this. And I think our witnesses were very open about the --

THE COURT: Yeah, they were.

MS. RONALD: -- concerns that we had about the, you know, lack of scientific sense, if you will, about some of the conclusions that you are faced with when you just have a strict application of the direction from the Courts that have looked at this before you. And so we -- we totally appreciate what you're talking about. It's -- it's -- and you're absolutely right, no matter what we do, somebody's not going to like it, and that's fine. That's the role that we play in this process, and we understand it.

The -- there are certain areas in the watershed that no matter what we do, no matter how many we look for, to use the terminology that people have put out, it's going to be very -- I'm going to use the word "subjective." We can call it professional judgment, we can call it a number of things.

THE COURT: But everybody acknowledges that.

MS. RONALD: Yes.

THE COURT: All of the experts acknowledge that you must use subjective, professional judgment.

MS. RONALD: So if we -- I'm sorry to interrupt.

THE COURT: No. No. I interrupted you. Go ahead.

MS. RONALD: Okay.

If we -- if we draw that curved line that everybody talks about, and it's slightly different than somebody else's curved line, in an area where there really are no guideposts, no matter what we do, you really can't figure it out, and so you just draw the line. We're willing to do that. We can draw lines on the map, but we need, you know, for -- and I think what you're telling us is it's okay to do that. And we'll have -- we can describe it.

THE COURT: As long as you can say why you did it, yes.

MS. RONALD: Yes. We can describe why we did it, what we looked at in order to try to provide more certainty about what we are doing.

I do have some concerns about how we are supposed to include floodplain Holocene alluvium that is underneath alluvial fans. We're supposed to include all of that.

THE COURT: Well, that's why I want you to perhaps think about submitting -- and we can talk about this now -- some type of proposal where you might do that.

All of the people that I cross-examined said that you can do that without actually going subsurface. All of them said they think there are way to -- to make a determination as to what's underneath the fans.

MS. RONALD: May I ask a point of clarification?

THE COURT: Yeah.

MS. RONALD: You said something about findings of fact from ADWR as well. Did I hear that?

THE COURT: No. I'm just --

MS. RONALD: Okay.

THE COURT: When we first started this -- when we first started this the -- I'm anticipating two forms. But the work I want for you, I think, is for you all, this is a perfect time for you to take what we've done, if Alternative B, as you refer to it, is what you think is -- is the avenue you should take, some of the parties all -- I heard a lot of, "I don't know what that is. I don't know what the Department means."

Well, I want you to tell me what it means. And I want to give the parties an opportunity to look at it, because part of this proceeding I want to not only make findings that were shown here, but based on those findings, directions of what you should do now. By sustaining the objections, I think it's only -- we're not going to get anyplace. We can say, "Okay. Because certain objections were sustained, where do you go from here?"

It doesn't mean you start over. It means how do you undertook -- undertake additional work to be confident, have a high confidence that you've identified the full extent of the floodplain Holocene alluvium. That's what I think the spirit of the X years of consideration has -- have been designed to do.

MS. RONALD: We agree, Your Honor. We're willing to do this.

THE COURT: But before you start, even though it's not going to prevent the objections, I want to have something from you to decide -- that describes, "Here's what we really mean the Alternative B," and perhaps modified. And then everyone can comment and say, "That's a good idea. That's a bad idea."

I've heard some of the experts say they're pretty close to you if what they think Alternative B is, is consistent with what you think it is.

MS. RONALD: What -- what were you thinking of in terms of timing for this proposal?

THE COURT: What do you think in terms of timing?

MS. RONALD: Well, how does it fit in with this other process where you're going to have --

THE COURT: It depends on what you say is the timing.

MS. RONALD: Did you want it before or after?

THE COURT: I want to make it as part of the order.

MS. RONALD: Oh, okay.

THE COURT: I want -- I want to put in the substantive order that there are findings of fact and conclusions of law, and based on those, the -- the objections are sustained to the extent they're consistent with what's been ordered to do. What's -- and what's being ordered to do is more than just look at topographical maps, surficial maps prepared by the entity you hired -- I'm not criticizing what they did; I'm saying it's just not enough. And you don't think it's enough either.

MS. RONALD: No, we don't, Your Honor, because there was some very legitimate comments that were made to the 2009 report, and we were aware of those issues when we put the 2009 report together so --

THE COURT: But I think it's a good time to start talking about what you're going to do because it will let -- it will let those that brought most of the objections see whether they can be consistent, and it will let those that oppose the objectors time to say, "Wait a minute. This is too much." I want to give you the opportunity to do the same thing.

MS. RONALD: When we were talking about a roadmap, we're talking about a description of a process --

THE COURT: Yes.

MS. RONALD: -- that we would undertake and perhaps --

THE COURT: Yes.

MS. RONALD: -- a couple of examples --

THE COURT: Yes. No specific findings or somebody will want another evidentiary hearing.

MS. RONALD: Okay.

THE COURT: Just, "Here the tools we plan to use," and I want it to be consistent that -- I want to be clear that there's no direction that you must use any given tool in any given site. It's -- it's -- the synergy that I heard explained here during the last three days was it's wrong for you to say you're always going to do the following things, because they may not apply in a certain area.

MS. RONALD: Judge, we totally agree with that. There's no one size fits all for the interior watershed along the San Pedro, the Bobo and the Aravaipa. That's clearly true. We agree with that.

Can I have a minute to talk to the people who would actually --

THE COURT: Well, Yeah.

MS. RONALD: -- have to do this?

THE COURT: Sure. Do that.

And so does anyone want to comment on what we're trying to do?

MR. LEMASTER: I just want to understand. I understand what the direction you're giving DWR. I'm somewhat confused about the process of where we go from here and how that relates to finding, timing. I mean, I'm just -- I understand what the Court wants, I'm just trying to put a process in place --

THE COURT: Okay.

MR. LEMASTER: -- that can be accomplished.

Are you saying that DWR provides you an outline of what they think that you said to do today, and then we then submit findings and conclusions to support it? We do our findings first?

I'm just kind of confused on that.

THE COURT: Okay. Let me try and help.

My idea would be to -- for a second to pretend like I didn't talk to Miss Ronald, and then say, "Okay. We're now just going to talk about what's reasonable to get the transcript to you all so you then can look at it and prepare your competing sets of findings of facts, conclusions of law and any substantive orders you think need to be derived from those two prior things. By the way, I need both of those in hard copy and Word format, please.

Then, while, we're dealing with that, separate from that I've asked the Department to say, "I'm already telling you that I'm going to sustain some of the objections and deny some of the others. So why don't you, the Department, while we're doing that, start working on, okay, what do you think you should do to supplement what you've done?" Then -- and we get into all of this, of course. Depending on how long they tell me it's going to take, in a perfect world, I would like to let everyone look at that. They, of course, can have input on their plan. But then I think it would be helpful if I put in the final order that I would sign direction based upon what they said and what comments I received from you. "Okay. This is what happened at this hearing. Here's what I want you to do next," so you can get to work on the next iteration that hopefully will at least be determinations by this Court of -- of the process that I hope they can use so that we -- when we go around, this won't happen, but so that when they come back with their next subflow zone map, I can say, "They did what I said. They used great -- they used their own judgment. Why do you think they didn't?" And make it quicker so that we can say, "Let's send it up. Let's send it up for the

Supremes."

Is that clear?

MR. LEMASTER: Maybe.

THE COURT: Okay.

MR. LEMASTER: I'm sorry.

THE COURT: That's the best I can hope for.

MR. LEMASTER: So we're going to -- we're going to submit our proposed findings and propose order regardless of what DWR is doing?

THE COURT: Correct right.

MR. LEMASTER: And then, once we get the DWR, we get to comment on it?

THE COURT: Yes.

MR. LEMASTER: And then from our comments and our proposed findings you're going to issue an order that tells DWR what to do.

THE COURT: Yeah. It's going to reflect the fact that I've overruled some of the objections, and granted the others, and it's going to be probably just as generic as to say to the extent consistent with the substantive order, because that's what's really important.

MR. LEMASTER: Right. I understand.

And just so timing, we're going -- we've still got 45 days --

THE COURT: Yeah, at least.

MR. LEMASTER: -- based on your order, assuming the transcripts --

THE COURT: At least.

Is that enough stall time for you to figure out what --

MS. RONALD: Yes. Thank you, Your Honor.

Based on this last conversation with Mr. Lemaster, I'm thinking that -- and, of course, conferring with the Department staff, we couldn't submit something within that same 45 days --

THE COURT: There you go.

MS. RONALD: -- so that, you know, there would be a simultaneous filing.

THE COURT: Okay.

So, is 30 days going to work?

(Off-the-record discussion held.)

THE COURT: So if we said that all -- that any proposed findings of fact and conclusions of law to the substantive form of order had to be submitted by April 2nd along with ADWR's perspective plan for supplementing the subflow zone delineation for the San Pedro watershed, everyone can live with that?

MS. RONALD: Yes. Thank you.

THE COURT: Okay. And you'll serve that.

And then any comments to ADWR's report --

April 27th? Anybody have a problem with that?

MR. ADAMS: Your Honor, Greg Adams.

One comment on behalf of ASARCO.

April 2nd is the same date the responsive briefs are due in the Trust Lands appeal before the Arizona Supreme Court, and I know many of the parties here are involved in that.

THE COURT: Okay. What date do you want?

MR. ADAMS: I mean, even if we had, you know, a couple days beyond that so the filing deadline --

THE COURT: How about the 9th? That's a week.

MR. ADAMS: That would be reasonable.

THE COURT: Okay. All right.

So that -- so that the simultaneous filing April 9th, due to the need of filing something in the Supreme Court.

MR. McGINNIS: We're -- we're sort of caucusing over here.

THE COURT: Okay.

MR. McGINNIS: I'm just wondering whether it might be better to have the DWR planned proposal, whatever it is, before the proposed findings and everything and not simultaneous with us. I was trying think of whether it would be to see that, it would be helpful to see that before --

THE COURT: I don't care.

MR. McGINNIS: -- before we do proposed findings --

THE COURT: You don't care, do you?

Do you want to do that too?

MR. LEMASTER: That would be fine Your Honor.

THE COURT: All right. So they'll file theirs by April 9th. And -- or actually, you don't have to file in the Supreme Court. You can do it April 2nd.

MS. RONALD: I can.

THE COURT: And then you can file your form of order, comments, whatever you want to call it, by the 27th?

MR. McGINNIS: It seems like that would make more sense.

MR. FINES: Your Honor, but one problem with that is we're going to have to read their proposal plus read the transcript all simultaneously, so I would ask for a little bit more time.

THE COURT: What do you want?

MR. FINES: Sometime around the middle of May, I would think, to do both.

MR. BARRY: And the United States and I think the Apache Tribe would join Mr. Fines on that because it's either the 26th or 27th, but we have at least a hundred objections due in Federal Court.

THE COURT: I'm really happy to accommodate you on this thing.

MR. BARRY: No. No. So we agree with him, mid May would be great.

THE COURT: May 25th. I mean, is that plenty of time?

MR. LEMASTER: Yes, Your Honor.

THE COURT: That gives you a long time to distill whatever the Department says.

Do you want more time, Miss Ronald, to submit yours?

MS. RONALD: Yes.

THE COURT: All right.

MS. RONALD: We do have some issues, resource issues, and so April 9th would work better for us.

THE COURT: Okay. Is that sufficient?

MS. RONALD: Is that too much of a problem for everyone else?

THE COURT: Is that good for you?

MS. RONALD: Yes.

(Off-the-record discussion held.)

MR. McGINNIS: Mr. Barry is asking me to clarify, and I want to make sure I'm clarifying right.

So the DWR plan is due on the 9th of April, and our proposed findings, conclusions of law, substantive orders and comments to their plan is due on May 25th.

THE COURT: Yes.

MR. McGINNIS: Thank you.

THE COURT: Okay. actually, it was pretty interesting. I enjoyed it. So than you all very much. You did a good job. And we'll talk to you later.

(Proceedings concluded.)

I, KIM J. HANNAN, do hereby certify that the foregoing numbered from 2-25, constitute a true and accurate transcript of my stenographic notes, taken at said time and place, all done to the best of my skill and ability.

DATED this 8th Day of February, 2012.

____

Kim J. Hannan

Certification # 50494

SUPERIOR COURT OF ARIZONA
MARICOPA COUNTY

01/26/2012 CLERK OF THE COURT
FORM V000

HONORABLE EDDWARD BALLINGER, JR. L. NEVENHOVEN
Deputy

W-1, W-2, W-3, W-4 (Consolidated)

Contested Case No. W1-103

FILED: February 21, 2012

In Re the General Adjudication
of All Rights to Use Water in
the Gila River System and Source

COPY

In Re: Evidentiary Hearing Day 3

MINUTE ENTRY

9:30 a.m. This is the time set for Evidentiary Hearing. Appearing are: Thomas L. Murphy on behalf of the Gila River Indian Community; Joe P. Sparks on behalf of the San Carlos Apache Tribe and the Tonto Apache Tribe; Mark A. McGinnis and Byron Lewis on behalf of Salt River Project ("SRP"); Rhett A. Billingsly, Sean T. Hood, and John C. Lemaster on behalf of Freeport McMoRan Corporation; F. Patrick Barry on behalf of the U. S. Department of Justice; L. Anthony Fines on behalf of Arizona Public Service Company; Gregory L. Adams on behalf of ASARCO LLC; R. Lee Leininger and Guss Guarino on behalf of the United States Department of Justice; Janet L. Ronald on behalf of the Arizona Department of Water Resources ("ADWR"); and Stephen C. Cann on behalf of the Nature Conservancy.

Court reporter, Kim Hannan, is present, as well as a record of the proceedings being made by CD/videotape.

Jeanmarie Haney is sworn and testifies.

ASARCO Exhibit 020 is received in evidence.

FMC Exhibit 024 is received in evidence.

The Witness is excused.
Oliver Page is sworn and testifies.

The Witness is excused.

11:30 a.m. The Court stands at recess.

1:02 p.m. Court reconvenes. Appearing are: Thomas L. Murphy on behalf of the Gila River Indian Community; Joe P. Sparks on behalf of the San Carlos Apache Tribe and the Tonto Apache Tribe; Mark A. McGinnis and Byron Lewis on behalf of Salt River Project ("SRP"); Rhett A. Billingsly, Sean T. Hood, and John C. Lemaster on behalf of Freeport McMoRan Corporation; F. Patrick Barry on behalf of the U. S. Department of Justice; L. Anthony Fines on behalf of Arizona Public Service Company; Gregory L. Adams on behalf of ASARCO LLC; R. Lee Leininger and Guss Guarino on behalf of the United States Department of Justice; Janet L. Ronald on behalf of the Arizona Department of Water Resources ("ADWR"); and Stephen C. Cann on behalf of the Nature Conservancy.

Court reporter, Kim Hannan, is present, as well as a record of the proceedings being made by CD/videotape.

Peter Mock is sworn and testifies.

SRP Exhibit 055 is marked for identification and received in evidence.

The Witness is excused.

LET THE RECORD REFLECT that exhibits were referred to but not specifically mentioned that were attached to witness affidavits and therefore not specifically received in evidence. The Court is willing to permit counsel to provide a stipulated list as to the actual exhibits referred to during these proceedings for consideration.

IT IS ORDERED directing counsel to submit a joint form of order regarding the exhibits received in evidence on or before March 23, 2012.

IT IS FURTHER ORDERED directing ADWR to submit a report detailing prospective work to be undertaken in an effort to delineate the subflow zone on or before April 2, 2012.

IT IS FURTHER ORDERED directing counsel to submit Findings of Fact and Conclusion of Law with comments regarding ADWR's report on or before May 25, 2012.

2:04 p.m. Matter concludes.

A copy of this order is mailed to all parties on the Court approved mailing list (Court) for Contested Case No. W-1-103 dated January 31, 2012.

SUPERIOR COURT OF ARIZONA
MARICOPA COUNTY

02/22/2012 CLERK OF THE COURT
FORM V000

HONORABLE EDDWARD BALLINGER, JR. L. NEVENHOVEN
Deputy

W-1, W-2, W-3, W-4 (Consolidated)

Contested Case No. W1-103

FILED: February 22, 2012

In Re the General Adjudication
of All Rights to Use Water in
the Gila River System and Source

COPY

In Re: Nunc Pro Tunc Minute Entry dated
January 26, 2012

NUNC PRO TUNC

Due to clerical error,

IT IS ORDERED nunc pro tunc amending Page 2 of the minute entry dated January 26, 2012, to indicate that ADWR shall submit a report detailing prospective work to be undertaken in an effort to delineate the subflow zone on or before **April 9, 2012**, in place and instead of April 2, 2012.

The remainder of the minute entry is unchanged.

A copy of this order is mailed to all parties on the Court approved mailing list (Court) for Contested Case No. W-1-103 dated January 31, 2012.