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Wednesday, December 01, 2021

Via Email and Hand Delivery
Garrick Baxter
Idaho Department of Water Resources
322 E. Front Street, Suite 648
Boise, Idaho 83702-7371

Re: Groundwater Management Planning in the Big Wood River Ground Water Management Area

Dear Garrick:

I write you on behalf of the Water District 37B Ground Water Association, comprised of Camas Prairie farmers and ranchers (the "Association"), in response to recent groundwater management planning efforts in the Big Wood River Ground Water Management Area ("Area"). The groundwater management planning efforts largely stem from the Department's recent contested case proceeding: *In the Matter of Basin 37 Administrative Proceeding* (IDWR Docket No. AA-WRA-2021-001) (the "Proceeding"), evaluating groundwater pumping effects in the Bellevue Triangle and Silver Creek, together with Director Spackman's related July 3, 2021 correspondence to Governor Little and House Speaker Bedke concerning the same ("Correspondence"). As you are likely aware, Director Spackman's July Correspondence initiated a series of Area management planning meetings under threat that:

> If, by December 1, 2021, a proposed groundwater management plan, mutually acceptable to ground water and surface water users in the Wood River Basin, is not submitted to the Director, or if the submitted proposed plan is unacceptable to the Director, the Director will immediately schedule a hearing for the Basin 37 Proceeding that is currently pending before the Director. The hearing will be scheduled to determine the actions the Director should take to ensure that ground water diversions in the Wood River Basin do not negatively affect the present or future use of any prior surface or ground water right.

Correspondence, p. 2.

The recent groundwater planning meetings (both advisory committee and technical working group) touched off instances of finger-pointing and demands for curtailment of groundwater pumping. Some of the finger-pointing and related curtailment threats have been directed at the Association. This led to confusion and questions concerning the reach and authority of the committee meetings and any potential curtailment request or result that may follow. The Association has voluntarily participated in these meetings to the extent that the Camas Basin aquifer system has been discussed, and the Association seeks amicable discussion and resolution of any impacts its members' groundwater pumping might have on the exercise of any interconnected senior surface water rights.[1]

However, the Camas Basin aquifer system has received scant discussion over these many months of meetings. Instead, discussion of the Silver Creek drainage has dominated, and understandably so in light of the scope and thrust of the Proceeding. Troubling, though, is the perception that some within the Department seemingly harbor the belief that meaningful Camas Basin aquifer surface water interconnection, particularly in the context of Magic Reservoir storage, exists and is a foregone conclusion despite the dearth of substantive discussion, investigation, and empirical evidence supporting such a conclusion.

While the Big Wood River side of the Area has benefitted from several years and several millions of dollars of research and discussion since 2015, the Camas Creek Basin has received almost none of the same comparatively speaking. Instead, the Association farmers and ranchers have spent roughly $150,000 of their own money conducting the only meaningful studies and research in the Camas Basin during the same time period. Thus, while the Association welcomes the opportunity to meaningfully discuss and data share over the to-this-point alleged and conclusory groundwater interconnection between Camas Creek and storage in Magic Reservoir, it takes a dim view of curtailment threats based on a stale, limited, and faulty technical record no matter the source of the threats.

Accordingly, I write you providing legal and scientific/technical context for the Association's position taken to date.

A. Procedural Background of Association Involvement in Area Groundwater Management Planning

1. Creation of the Big Wood River Ground Water Management Area in June 1991

The Association membership acknowledges its geographic inclusion within the exterior boundary of the Area. *See Order* (Jun. 28, 1991; "Order"), *In the Matter of Designating the Big Wood River Ground Water Management Area*, p. 2 and Attachment 1. For its part, the Order drew no hard conclusions concerning groundwater-surface water interconnection, at least with respect to the Camas Basin.

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[1] To this end, the Association voluntarily advanced the attached management proposal "term sheet" on November 22, 2021, during the afternoon advisory committee meeting.

Ultimately, and despite better understanding of groundwater and surface water interconnection in the Big Wood River Basin, the Order left questions concerning any potential interconnection-based injury unresolved. Instead, the Order more generally raised the potential for injury as opposed to finding any actual injury. Order, p. 1, Finding of Fact No. 4 (emphasis added) ("***Injury could occur*** to prior surface . . . rights including the storage right in Magic Reservoir ***if the flows of streams***, rivers and ground water underflow . . . ***are intercepted by junior priority ground water diversions***."). Consequently, the Order formed the Area "to allow increased management" in order to determine "whether withdrawals from existing and proposed wells will have an adverse impact on prior water rights . . ." Order, pp. 1-2, Conclusion of Law Nos. 2-4.

2. 2015 Attempted Delivery Calls of The Big Wood and Little Wood Water Users Association (Docket Nos. CM-DC-2015-001 & 002)

In February 2015, the Big Wood and Little Wood Water Users Association attempted to prosecute delivery calls under the Department's administrative Conjunctive Management Rules. The "petitions" for delivery call took the form of two letters addressed to the Director, dated February 24, 2015. The Director then used the letters to initiate the above-referenced consolidated contested case proceeding (Docket Nos. CM-DC-2015-001 & 002) (collectively "CM Proceeding").

The CM Proceeding resulted in a flurry of administrative litigation involving numerous parties, including the Association who formally joined in the proceeding on July 10, 2015 via appearance of counsel. *Notice of Appearance* (Jul. 10, 2015). While the CM Proceeding was live, various staff memoranda issued in response to Director requests for the same. *See, e.g.*, *Hydrology, Hydrogeology, and Hydrogeologic Data, Big Wood & Little Wood Water Users Association Delivery Calls, CM-DC-2015-001 and CM-DC-2015-002* (Aug. 28, 2015) ("2015 Sukow Memo"). Among other things, the 2015 Sukow Memo attempted to catalogue "hydrologic or hydrogeologic data or publications . . . that may assist the Director in understanding surface and ground water interactions in the Big and Little Wood River basins." 2015 Sukow Memo, p. 1. The 2015 Sukow Memo also advanced a "conceptual description of the interaction between ground water and surface water in the Camas Creek drainage, the Big Wood River drainage, the Silver Creek drainage, the Little Wood River drainage, and any other hydrologic units that may be hydraulically connected to ground water and surface water in the larger Big Wood River and Little Wood River basins." *Id.*

Ultimately, the CM Proceeding never made it to hearing. Instead, the matter was dismissed in its entirety on remand from interlocutory order district court judicial review on the grounds that the Big Wood and Little Wood Water Users Associations "failed to satisfy both the filing and service requirements of Rule 30 [of the Conjunctive Management Rules] to the prejudice of the substantial rights of Sun Valley [Company], the Cities of Fairfield and Ketchum, and the Water District 37B Ground Water Association." *See, e.g.*, *Final Order Dismissing Delivery Calls* (Jun. 22, 2016). Consequently, the contents of the 2015 Sukow Memo went unvetted and untested by parties to the CM Proceeding.

3. 2017 Attempted Delivery Call of The Big Wood and Little Wood Water Users Association (Docket No. CM-DC-2017-001)

On March 6, 2017, the Big Wood and Little Wood Water Users Association again attempted a delivery call for administration of senior surface water rights and interconnected junior groundwater rights—this time via a formal *Petition for Administration* (the "Call"). The 2017 Call did not seek administration of interconnected surface and groundwater rights in the Camas Basin, to the extent any interconnection exists; rather the Call sought administration of rights located within the narrower boundary of the "Wood River Valley Aquifer Model study area." Call, ¶¶ 5-7; *see also*, *id*., Exs. C and E.

Though the Call did not implicate the Camas Basin, it was an outgrowth of the failed 2015 CM Proceeding. The 2017 Call, too, failed to make it to hearing. The Call was ultimately dismissed for the petitioner association's failure to comply with Conjunctive Management Rules 30 and 42—the petitioner association lacked the standing required to prosecute the Call in the absence of the joinder of its actual (and indispensable) members as parties to the contested case. *See Order Dismissing Petition for Administration* (Jun. 7, 2017), generally.

4. The 2021 Proceeding (Docket No. AA-WRA-2021-001)

The 2015 CM Proceeding and the 2017 Call initiated several years and several millions of dollars of studies and modeling attempting to better understand surface water and groundwater interconnections in the model area identified in the 2017 Call—several years and several millions of dollars that ***did not*** include the Camas Basin. Much of this work culminated in the Department's recent contested case proceeding: *In the Matter of Basin 37 Administrative Proceeding* (Docket No. AA-WRA-2021-001). However, the posture of the 2021 Proceeding differed significantly from that of its 2015 and 2017 predecessors. The 2021 Proceeding was not a delivery call-based petition for administration under the Department's Conjunctive Management Rules. Instead, the 2021 Proceeding was initiated by the Director *sua sponte* under Idaho Code Section 42-237a.g. *See*, *e.g.*, *Notice of Administrative Proceeding, Pre-Hearing Conference, and Hearing* (May 4, 2021) (the "Notice").

The Notice caused some initial confusion over whether the Camas Basin and, therefore, the Association were implicated. On the one hand, the Association members received copies of the Notice. On the other hand, Notice Attachment A (mapping and depicting the "Potential Area of Curtailment") clearly omitted the Camas Basin and the Big Wood River Basin north of the City of Bellevue from inclusion in the Proceeding. This confusion continued in light of the Director's *Request for Staff Memorandum* (May 11, 2021) which, among other things, sought staff comment on "the hydrology and hydrogeology of the Big Wood River, Little Wood River, Silver Creek, ***and Camas Basins***," lumping all of the foregoing basins into the "Wood River Basins." *Request for Staff Memorandum*, p. 1 (emphasis added).

Ultimately, the confusion was resolved through subsequent documentation expressly omitting the Camas Basin from the 2021 Proceeding. This is because the Proceeding was focused on the Silver Creek drainage and the related boundary of the WRV V1.1 groundwater flow model, neither of which are connected to, or touch upon the Camas Basin. *See*, *e.g.*, *Predicted Hydrologic Response in Silver Creek and the Little Wood River to Curtailment of Groundwater*

Use in 2021, Basin 37 Administrative Proceeding, AA-WRA-2021-001 (Corrected Jun. 8, 2021) ("2021 Sukow Memo"), Figs. 2 and 17 (depicting the WRV V1.1 model boundary), and pp. 2 (noting that the Camas Prairie aquifer system "do[es] not interact with Silver Creek or the Little Wood River"), 12 ("Groundwater development in the Camas Prairie aquifer system . . . is not hydraulically connected to Silver Creek or the Little Wood River, and is not discussed further in this memorandum"), and 29 (reiterating and concluding the same lack of Camas Basin interconnection and lack of relevance to the Proceeding). The Director's *Final Order* (Jun. 28, 2021) conclusively ended any potential doubt over the omission of Camas Basin hydrology and hydrogeology from the 2021 Proceeding. *Final Order*, p. 2 (citing 2021 Sukow Memo at Fig. 17 as the external boundary of the "Potential Area of Curtailment" for purposes of the Proceeding); *see also, id.*, p. 3 ("Camas Creek flows into Magic Reservoir from the west. The hydrologic relationship of ground water pumping in the Camas Creek Basin to other surface water sources in the Wood River Basin is not evaluated by this decision.").

To the extent the Camas Basin was tangentially discussed initially in the 2021 Proceeding, that discussion/evaluation was fleeting at best and, essentially, based upon regurgitation of the scant, incomplete, and outdated data and publications cited in the 2015 Sukow Memo. *See, e.g.*, 2021 Sukow Memo, pp. 2 ("The hydrology and hydrogeology of the Big and Little Wood River basin was described in a staff memorandum for a previous proceeding (Sukow 2015). The previous memorandum (Attachment A) describes the occurrence of aquifers within Basin 37 and their interaction with surface water (Figure 1)"); and 12 ("Ground water development in the Camas Prairie aquifer system was discussed in Sukow (2015)").[2]

5. Apparent Leveraging of the 2021 Proceeding Beyond its Scope

As discussed above, some have suggested to the Association that it needs participate in 2021 Proceeding-related groundwater management planning "or else" face the likelihood of curtailment. The Director's July 3, 2021 letter to Speaker Bedke and Governor Little setting a December 1, 2021 deadline for management plan submission is often cited for this proposition. However, the Camas Basin ***was not*** geographically part of, nor the Association party to, the 2021 Proceeding. Thus, the Director's stated remedy in response to any recalcitrant Proceeding participants to "immediately schedule[ing] a hearing for the Basin 37 Proceeding that is currently pending before the Director" does not include or apply to the Camas Basin.

Said differently, the Association's location in the larger Area does not automatically bring it under purview of the Proceeding or the Director's July correspondence. The Association's participation in any current groundwater management planning is not an outgrowth of anything determined in the 2021 Proceeding. Instead, Association participation at this point seemingly derives from the broader and more general auspices of the Groundwater Act (Idaho Code §§ 42-226 - 42-239); more particularly, Idaho Code Section 42-233b in the context of the Area.

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[2] Notably absent from the 2015 Sukow Memo is reference to, let alone discussion of, the peer-reviewed and journal-published work Brian Cluer: *Storage Basin Volume and Drainage Basin Dynamics: Camas Prairie, South-Central Idaho* (1989), published in Vol. 27, No. 3 *Ground Water* (May-June 1989) (courtesy copy attached hereto).

Under the Act, the purpose of groundwater management planning is to "manag[e] the effects of ground water withdrawals on the aquifer from which withdrawals are made and on any other hydraulically connected sources of water." IDAHO CODE § 42-233b. From there, it is the Director's duty to administer such water rights on a priority basis "upon determination that the groundwater supply is insufficient to meet the demands of water rights within all or portions of a water management area." *Id*.

The Association does not question the authority of the Director (or the Department) to proceed with groundwater management planning in designated groundwater management areas. But, the Association is concerned with repeated statements of some during the last several months pre-supposing in an entirely conclusory manner that interconnected "effects" have been "determined" concerning the Camas Basin, and that potentially curtailment-based approaches (or management plans) are needed for "managing those effects." To the contrary, one cannot attempt to meaningfully "manage" the alleged "effects" of something without a thorough understanding of the effects, if any, one seeks to manage/mitigate.

Consistent with Idaho Code Section 42-233b, proceedings and administration occurring under Idaho Code Section 42-237a.g. require threshold determinations before administration occurs. As will be discussed in Section B below, there are legitimate questions over whether the Camas Basin—or at least the portion of the basin west of the confluence of Willow and Camas Creeks—shares a "common water supply" with the northern and eastern portions of the Area, particularly in the context of alleged ground and surface water interconnections. Similarly, administration triggers under the statute only after determination that exercise of a junior groundwater right (or rights): (a) "would affect . . . the present of future use of any prior surface or ground water right"; or (b) "result in the withdrawing of the ground water supply at a rate beyond the reasonably anticipated average rate of future natural recharge." IDAHO CODE § 42-237a.g. Where have such determinations of "affect" and/or aquifer mining in the Camas Basin been made and catalogued?

Such determinations were not made in the 2021 Proceeding. And, if they stem from the 2015 Sukow Memo, or other staff-level "studies," those determinations remain opaque, essentially unvetted, and entirely untested. Again, the Big Wood River Basin has benefitted from several years (at least 6) and several millions of dollars (approximately $5 Million I've been told) of study leading into the 2021 Proceeding. The Camas Basin, by comparison, has benefitted from nothing of the sort—nothing, that is, outside the approximately $150,000 spent by the Association farmers and ranchers to date taking matters into their own hands in an effort to educate themselves and others regarding the groundwater complexities of the Camas Basin.[3]

As you know, water rights are real property rights begetting due process entitlements before they may be administered, curtailed, or taken. *See, e.g.*, *Nettleton v. Higginson*, 98 Idaho 87, 90, 588

[3] The Association acknowledges and appreciates the Department's assumption of its (the Association's) preexisting groundwater level monitoring network data collection. But, that assumption of data collection and web-based posting pale in comparison by orders of magnitude to the Department's work in the Big Wood River Basin and to the efforts of the Association farmers and ranchers.

P.2d 1048, 1051 (1977). This said, the Association members understand that they do not have a property interest in being free from the State's regulation of the public water resource. *See, e.g., Idaho Dep't of Water Res. Amended Final Order Creating Water Dist. No. 170 v. Idaho Dep't of Water Res.*, 148 Idaho 200, 213-214, 220 P.3d 318, 331-332 (2009). However, if something or someone is going to demand a pound of flesh under the auspices of groundwater management planning, then certain threshold determinations need first be made and vetted. Because some merely "say" or "think" that a Camas Basin aquifer-to-surface water interconnection exists is not good enough. The Camas Basin is a unique, complex hydrologic and hydrogeologic basin and system unto itself nothing like the comparatively straightforward ground and surface water interconnections of the Silver Creek drainage examined during the 2021 Proceeding.

B. Modern Research, Data Collection, and Review Concerning the Camas Prairie Basin Aquifer System

As discussed above, Idaho Code Sections 42-233b and 42-237a.g. are generally concerned with three determinations: (a) areas of common groundwater supply; (b) "effects" or "affects" of junior groundwater withdrawals on senior ground and surface water rights; and (c) avoidance of aquifer mining (withdrawals exceeding natural rate of recharge) unless it is consistent with the public interest to do so, and further provided that injury is avoided. As also discussed above, the Association farmers and ranchers have spent more than $150,000 and parts of the last 6 years (2021 in particular) researching the nature, scope, and resiliency of the Camas Rift Basin aquifer system, including its interconnection, if any, with surface water flows in Camas Creek. Attached are a handful of "big picture" slides/graphics of the Association's efforts and findings to date indicating that[4]:

1. Existing groundwater-based irrigation diversions in the Camas Basin (~10kAF to 13kAF annually) ***are not*** depleting or mining the aquifer. Water measurements in the Strom, McLam, Schmidt, and Ix-Nay, wells undertaken initially by the Association and now taken and reported by IDWR show stable to ***increasing*** water level trends over the last 6 years with water levels in wells equal to, or above, water levels measured and reported when the wells were drilled decades earlier. Rising groundwater levels indicate increasing aquifer storage and an increasing/rising water table, ***not*** the opposite condition of groundwater depletion;

2. Artesian wells in the Camas Basin continue to flow at land surface (even during the drought-stricken fall and early winter of 2021) ***contrary to*** the 1962 reported predictions of W.C. Walton (a core citation of the 1962 "Walton conceptual model" in the 2015 Sukow Memo);

3. The LDS Church well static water level has declined only approximately 15 feet over the past 50 years—***not*** the 150 feet-plus predicted by Walton in 1962, and much of the

[4] The Association acknowledges that much of its data is preliminary, and that review and interpretation leading to firmer conclusions remains a work in progress. But, data-based trends and conclusions, no matter how preliminary, are emerging warranting further investigation, discussion, and development.

decline is attributable to well construction characteristics and its location in close proximity to continuously-pumped, more modern municipal wells owned and operated by the City of Fairfield;

4. Camas Creek streamflow measurements between its confluence with Willow Creek and the confluence of Camas Creek with the Big Wood River demonstrate that lower Camas Creek is, overall, a ***losing stream reach*** (though not studied separately by the Association, it is universally and generally accepted that Camas Creek from approximately 1 mile upstream of the Willow Creek confluence to the Camas Creek headwaters is also a losing stream);

5. Camas Creek streamflow, temperature, and specific conductance measurements between the confluence of Willow Creek and the confluence of Camas Creek and the Big Wood River demonstrate that groundwater expression/influence on Camas Creek enters from the north and not the west (*i.e.*, Association farmer and rancher groundwater pumping is upgradient to (and west of) Willow Creek, while the prevailing groundwater flow Willow Creek to the confluence with the Big Wood River is north to south);

6. Statistical analyses of seasonal Camas Creek surface flow discharge data from 1962-1982 (20 year period prior to completion of irrigation-based groundwater development in the basin) and from 1982-2002 (20 year period after completion of irrigation-based groundwater development in the basin) demonstrates significant declines in precipitation-based spring runoff (dovetailing a generally accepted trend of an approximate 20% decrease in snowpack documented across the intermountain west) and virtually no change in mid-to-late season surface water flows post-snow melt runoff (*i.e.*, stream baseflow trends remain remarkably stable over both periods of time);

7. Historical aerial image comparison of the Magic Reservoir "dead pool" pre- and post-irrigation groundwater development shows the same 7kAF to 8kAF contents—that pool is likely the top of the groundwater table at 4,717-foot elevation and has remained unchanged for at least 47 years[5];

8. Significant ungauged surface water inflows into Magic Reservoir create substantial data gaps concerning the filling and operation of the reservoir for water right administration purposes (both those of the Big Wood Canal Company and others); and

9. Preliminary LIDAR data analysis suggests a significant discrepancy between true Magic Reservoir storage volume and typical operations versus that legally authorized under the storage water rights supplying the reservoir (which rights total 191,500 AF).

The Association does not dispute groundwater in- and underflow within the Camas Basin. But, assertions by others that lower Camas Creek (below the confluence of Willow Creek) is, overall, a gaining stream, and that those gains are the expression of the Camas Basin aquifer spanning

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[5] The Big Wood Canal Company states that this pool comprises 4% (or 7,660 AF) of the fill volume (191,500 AF) of Magic Reservoir.

roughly 50 miles long and 5 miles wide are proving increasingly incorrect as more data is gathered and evaluated.

The groundwater of any consequence flowing into and under lower Camas Creek during late season baseflows enters from the drainages and volcanic geology to the north, not the larger sedimentary Camas Basin aquifer located to the west. Streamflow measurements taken throughout lower Camas Creek in 2021 (one of the most significant drought years on record) show temporary lower Camas Creek flow gains where groundwater-influenced surface water streams enter from the north (*e.g.*, at/near the tributary confluences of Willow Creek, Camp Creek, Spring Creek, and Poison Creek). But, those gains in lower Camas Creek are short-lived, mounding and dissipating (leaking from the creek) until the next drainage enters from the north. This is particularly pronounced between Moonstone Landing and the confluence of Camas Creek with the Big Wood River.

If, on the other hand, the Willow Creek "nick point" was the start (or in vicinity of the start) of where the larger Camas Basin aquifer expressed itself, one would expect to see springs emanating from the basalt canyon walls similar to the Thousand Springs reach of the Snake River, or at least historic evidence (stranded vegetation, vegetation remnants, water lines, staining, etc.) of the same based on the logged and monitored groundwater elevations and creek bed elevation loss as Camas Creek flows from west to east. However, no such evidence exists within the entire lower 10 miles of Camas Creek above its confluence with the Big Wood River. Similarly, if the aquifer were depleting and losing water table elevation, one would expect to see evidence of that exposed in the basalt lower Camas Creek bed (rock staining, deeper bed scour patterns from spring runoff) but, again, no such evidence exists.

The highly consistent and controlled fall/early winter seasonal discharge to lower Camas Creek specifically located at the confluence of Willow Creek and extending downstream from there further indicates that the groundwater influence of any consequence enters from the north, not from the west where Association member groundwater use occurs. This is because in wildly fluctuating years (big water years and drought years), the inflow mounding and dissipation pattern persists and consistently begins at the Willow Creek confluence. The Association finds no evidence of mounding and gaining reaches moving upstream in lower Camas Creek during or after big water years, nor movement of the same downstream during or after drought years (one would expect groundwater expression to increase and move upstream in and around big water years owing to increased groundwater elevation and head pressure and the opposite to occur in and around drought years with declining groundwater elevations and head pressure).

Finally, the consistency of the Magic Reservoir dead pool (~8kAF) and its surface elevation, especially in drought years pre- and post-groundwater development in the Camas Basin, is telling. If Association member pumping were depleting the Camas Basin aquifer as some allege, and the larger aquifer were meaningfully connected to lower Camas Creek and Magic Reservoir, the reservoir dead pool should shrink/decrease in size, volume, and elevation. But it has not.

Moreover, further indicating that the filling of Magic Reservoir is dependent upon flashy, high volume surface water runoff is five months of reservoir surface water inflows (~7,500 AF from ~25 cfs continuously entering the reservoir from mid-June 2021 to date), while the reservoir water level elevation measured at the dam gauge has not increased appreciably. Instead, reservoir inflows are increasing head pressure and likely pushing water down and out of the reservoir even at this low head condition (imagine this "leakage" when an additional ~120 feet of head is applied when the reservoir is at full pool and, incrementally, every elevation in between). Groundwater does not contribute to the filling of the reservoir; rather the reservoir consistently and continuously contributes (*i.e.*, loses) water to the groundwater through the highly fractured, jointed, and bouldered basalt bottom and sides of the "bucket"—that is until surface water inflows from the spring runoff are of a great enough quantity and magnitude as to overcome reservoir leakage and outflow.[6]

As noted in the above discussion of Idaho Code Section 42-233b, and demonstrated by roughly 6 years and $5 Million of study and model development in the Big Wood River Basin, the first step to managing groundwater is understanding its hydrology and hydrogeology as a threshold matter. The Association farmers and ranchers are committed to further developing the science and understanding of the groundwater aquifer(s) of the Camas Basin so that sound and informed decisions can be made.

C. The Association's "Term Sheet" Proposals

The foregoing is context for the Association's "term sheet" submittal. Apologies in advance if you or others find the tenor of this correspondence to be combative—that is not the intent. Instead, the purpose of this correspondence is to be pithy and direct—a variety of legal and factual (*i.e.*, scientific/technical) gaps exist, certainly more so than some participants in the technical working group and the advisory committee meetings over the last several months acknowledge or understand. The Association's term sheet is not without legitimate and good faith basis; rather it is based on substantial data and analysis developed by the Association. Those who may be disappointed by the contents of the term sheet are the same who pre-suppose various hydrologic and hydrogeologic determinations, based on flawed and outdated data, that have yet to be conclusively made.

In closing, and consistent with Idaho Code Section 42-231 (instructing all-involved that "investigations, surveys and studies" are to lead the way), the Association's term sheet tips strongly in a continuing research direction. The Association requests that the Department, again consistent with Idaho Code Section 42-231, "enter into cooperative investigations, researches, and studies" with it so that the science and not adversarial litigation can lead the way. The livelihoods of fourth generation Association farmers and ranchers, and the socioeconomic fabric of the Camas Prairie community, depend on it. The Camas Prairie deserves no less than the

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6 This "leakage," coupled with evaporation, ungauged runoff and stream inflow, known gauge error, and storage water accounting based on physical water level elevation at the dam all add to a very significant volume of unaccounted for water inherent in Magic Reservoir operations. The total groundwater withdrawal pumped from the Camas Basin aquifer system is immaterial by comparison. If curtailment is requested (or mandated) of the Association farmers and ranchers, they are entitled to a thorough and detailed review and vetting of Magic Reservoir operations and storage water accounting as a threshold matter.

many and millions of dollars of research provided the water users to the east in the Big Wood River Basin.[7]

Thank you in advance for your review and consideration of this matter. If you or others within the Department think it helpful, the Association would appreciate the opportunity to present updates to its findings last presented in February 2021. Just let us know.

Hopefully the winter of 2021/22 will be remembered for copious precipitation and snowpack to the benefit of everyone, and not something else.

Very truly yours,

Andrew J. Waldera

AJW/dll
Enclosures
c: Client
Shelley Keen (via email only)
Tim Luke (via email only)

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7 Various discussions amongst the stakeholders continue as today's deadline looms. The Association expects these discussions will continue. However, the Camas Basin has been, and largely remains, an afterthought in the vast majority of these discussions. Nevertheless, the Association will continue participating when afforded the opportunity to do so. In the meantime, the Association's term sheet remains what it is unless and until other requests or proposals materialize for its review and consideration.

WATER DISTRICT 37B GROUND WATER ASSOCIATION

PROPOSED GROUND WATER MANAGEMENT PLAN "TERM SHEET"

11/22/2021

The Water District 37B Ground Water Association (comprised of Camas Prairie farmers—collectively, the "Association"), though not geographically part of or otherwise party to the 2021 IDWR contested case proceeding *In the Matter of Basin 37 Administrative Proceeding* (Docket No. AA-WRA-2021-001) (the "Proceeding") and, therefore, not part of Director Spackman's July 3, 2021 correspondence addressed to Governor Little and House Speaker Bedke setting a December 1, 2021 deadline for submission of a proposed groundwater management plan in lieu of resuming "the Basin 37 Proceeding that is currently pending before the Director," voluntarily submits the following groundwater management plan commitment proposals in light of the Association's location within the larger Big Wood River Ground Water Management Area ("BWGWMA"). *Order* (Jun. 28, 1991).

The Association's position will be explained in greater substance and detail in subsequent correspondence submitted by it on or before December 1, 2021. However, the Association voluntarily advances the following commitments in the interim despite the facts that:

(a) meaningful review and discussion of the Camas Prairie Basin aquifer system has been essentially non-existent during these advisory and technical workgroup meetings (focusing instead on groundwater and surface water interconnections in the Silver Creek drainage consistent with the defined scope and thrust of the Proceeding); and

(b) inclusion of the vast majority of the Camas Prairie Basin within the BWGWMA is questionable at best because it is based on limited, outdated, and increasingly faulty technical data. In fact, data collected and analyzed from 2015 to date demonstrates that ground water contributes little-to-no water volume to surface flows in Camas Creek and Magic Reservoir downstream, which reservoir is filled almost entirely (96%) from the surface water spring runoff from the Soldier Mountains on the north side of the basin.

Nevertheless, in the spirit of good faith cooperation, and subject to and consistent with the supplemental explanatory correspondence forthcoming on or before December 1, 2021, the Association commits to the following actions in future drought years until such time as its membership is no longer part of the BWGWMA:

- Delaying the beginning of irrigation groundwater pumping until May 1 and concluding irrigation pumping by September 15 (the authorized irrigation season of use is generally April 15 to October 31—though some groundwater right seasons of use extend from March 15 thru November 15). This season of use reduction will restrict alfalfa production to two cuttings only and affect/restrict barley and other crop plantings/rotations as well;

- The Association will contribute $10,000 to cloud-seeding efforts in the Big Wood River Basin (this financial commitment doubles the existing $5,000 annual contribution of Water District 37B, resulting in an overall contribution of $15,000 by the District and the Association for cloud-seeding efforts that provide no benefit to the Camas Creek drainage); and

- The Association commits to continue funding, in whole or in part (including thru cost-share and grant opportunities), its own continuing scientific review and research of the Camas Prairie Basin aquifer system on top of approximately $150,000 already spent by the Association to date. Studies, research, and reports to include:

  (a) analyzing and estimating currently ungauged streamflow into Magic Reservoir from, among others, Rock Creek, Poison Creek, Camp Creek, Spring Creek, and Lava Creek;

  (b) evaluating and refining LIDAR data to determine existing/current true water storage capacity of Magic Reservoir after roughly a century of infill and sedimentation;

  (c) performing statistical (including regression) analysis of historic streamflow pre- and post-groundwater development in the Camas Basin;

  (d) analyzing and reporting on continuous groundwater level monitoring in Camas Prairie Basin wells from September 2015 to present;

  (e) performing statistical analysis of historical filling/storage volumes of Magic Reservoir comparing pre- and post-groundwater development periods in the Camas Basin;

  (f) performing, analyzing, interpreting, and reporting conductivity and temperature sampling (including geochemistry analysis) to determine groundwater source contributions, if any, to Lower Camas Creek;

  (g) conducting and reporting streamflow measurements in Lower Camas Creek (from 1 mile above the confluence of Willow Creek to the Camas Creek confluence with the Big Wood River) with associated interpretation and conclusionary reports;

(h) designing, conducting, analyzing, and reporting on multi-well aquifer testing of Camas Basin sub-aquifers; and

(i) Reviewing in depth, interpreting, and reporting on all previous scientific research and papers pertaining to the Camas Rift Basin Aquifer to dispel concepts that have been proven false over time, and to build on concepts that continue to be supported by recent studies.

The Association will compile and report all data it amasses to IDWR so that sound, modern technical data and conclusions inform any ongoing Association member participation within the larger boundaries of the BWGWMA and groundwater management within the same. These technical study/data development commitments are significant in light of the fact that the Big Wood River Basin has benefitted from several years and several millions of dollars of study and groundwater model development while the Camas Prairie Basin, by comparison, has received almost no Legislative funding and/or hydrologic/hydrogeologic study beyond the efforts of the Association member farmers and their hydrogeological consultants—even though the Camas Prairie Rift is a ground water basin in its own right (not a simple tributary stream of the Big Wood River) and, indeed, a much more complex ground water system than that of the Big Wood.

Storage Basin Volume and Drainage Basin Dynamics: Camas Prairie, South-Central Idaho

by Brian L. Cluer[a]

ABSTRACT

A recent tectonic model and subsequent gravity survey and basement modeling have raised questions concerning the size of the Camas Prairie ground-water storage basin and the hydrodynamic properties of the Camas Creek drainage basin. This paper addresses storage basin dimensions using an anomalous mass determination from a plot of residual gravity, and presents estimates of recharge and underflow from a mass-balance study. Underflow may transport much of the water [$2.73(10^5)$ acre-feet/yr] (ac-ft/yr) calculated as residual in the mass-balance study, and transport is from the Camas Prairie storage basin south to the Snake Plain Aquifer via permeable strata in the Mount Bennett Hills surface drainage divide. Results of the anomalous mass study suggest that the volume of ground water stored in the Camas Prairie basin is $39(10^6)$ ac-ft, considerably greater than previously estimated. Similarly, recharge to the Camas Prairie basin is estimated at over $7(10^5)$ ac-ft/yr, one order of magnitude greater than earlier estimates.

INTRODUCTION

General Geology

The Camas Prairie, Idaho, is an intermontaine structural basin approximately 70 km (45 miles) long and 15-25 km (10-15 miles) wide. It is centered on the northern margin of the Snake River Plain in southern Idaho (Figure 1). The basin drains to the east via Camas Creek, which combines with the Wood River at Magic Reservoir to form the Big Wood River (see Figure 5 for stream locations), a tributary to the Snake River.

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Mountains composed of various igneous and metasedimentary rocks surround the Camas Prairie (Figure 2). North of the basin, the most prominent outcrop is the Soldier Mountains, the southern limit of the Idaho batholith, with elevations in excess of 3 km (10,000 ft). They are composed mostly of late Cretaceous to early Tertiary granodiorite and related intrusives. Younger extrusive rocks make up the remainder of the northern mountains. Subordinate in size and age are the

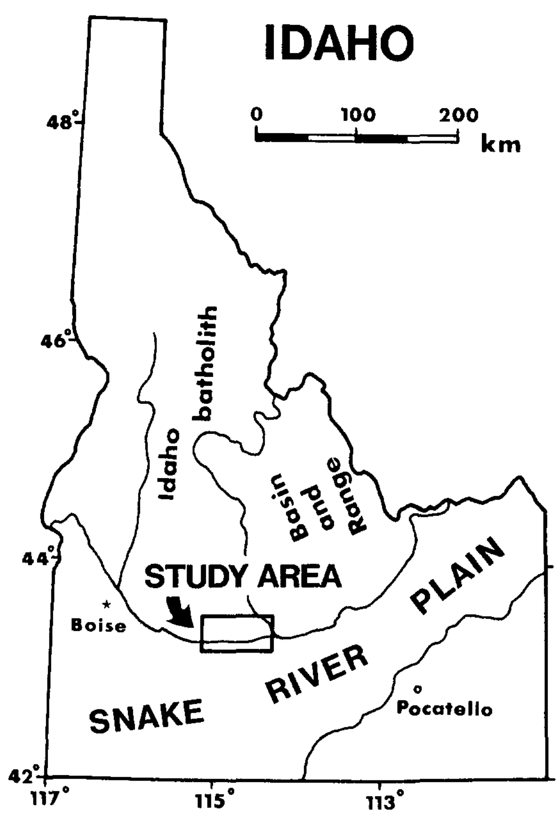

Fig. 1. Location map of the study area in south-central Idaho. General boundaries of the Snake River Plain, Basin and Range, and the Idaho batholith are outlined.

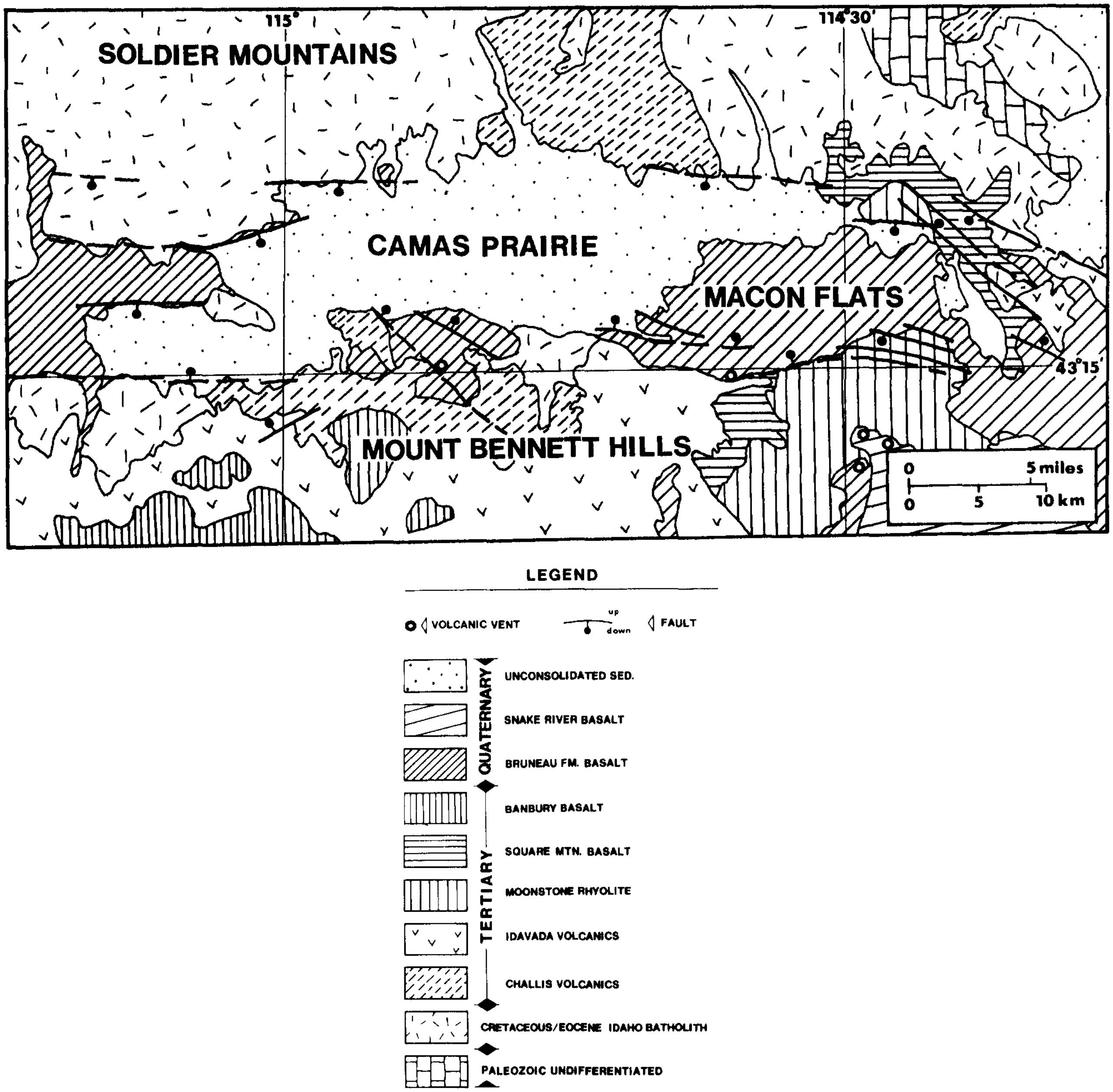

Fig. 2. Generalized geologic map of the Camas Prairie and surrounding area, with accompanying legend. Modified from Cluer, 1987.

Eocene Challis Volcanics, composed of a broad range of silicic volcanic and volcaniclastic materials.

The Mount Bennett Hills bound the basin on the south side. This range, which rises abruptly along high-angle normal faults (Cluer and Cluer, 1986) to elevations of 2 km (6300 ft), is composed mostly of Miocene to Pliocene basalt flows, rhyolite intrusions, and various other volcanic products, all of which are related to orogenesis of the Snake River Plain. Small outcrops of granitic rock are enclosed within this volcanic construct. Also found in the Mount Bennett Hills are several outcrops of alluvial material containing exotic clasts of meta-sedimentary rocks that exist only in the mountains north of the Camas Prairie (Cluer and Cluer, 1986).

Quaternary alluvium and Pliocene to Quaternary basalt flows (individual flows have been dated by Armstrong and others, 1975 and 1980; Leeman, 1982; and Struhsacker and others, 1982) make up the Camas Prairie surface. Although remarkably flat, the basin surface is tilted east, and elevations range from 1.7 km (5400 ft) above mean sea level at its western end, to 1.5 km (4800 ft) at the eastern outlet.

Problem, Purpose of Study

A tectonic model for the Camas Prairie (Cluer and Cluer, 1986) presents geologic evidence indicating that the east-west oriented structural basin (an anomaly in this region) subsided along normal faults in response to shortening of the central Snake River Plain (the "Snake River downwarp" of Kirkham, 1931). Cluer and Cluer (1986) named this basin the "Camas Prairie Rift," in part to emphasize its structural association to the Snake River Plain and also to draw attention to their estimate of basin depth versus earlier reports of probable basin depth used in ground water (Piper, 1926; and Walton, 1962) and geothermal investigations (Mitchell, 1976). A recent gravity survey and two-dimensional modeling of the basin (Cluer, 1987) lend support to this tectonic model for the Camas Prairie basin. The implications of a structural orogenesis for the Camas Prairie basin are numerous and diverse. From a hydrogeologic view, the implications are: (1) the alluvial basin may be much deeper and greater in storage volume than previously believed; (2) the southern basin boundary (the structurally controlled Mount Bennett Hills) may juxtapose permeable strata below the water table. These implications are addressed in this paper.

During 1986, the author collected 371 gravity measurements at 286 different locations within the Camas Prairie. Station spacing for this survey was one measurement for every square mile. These data were combined with 152 gravity stations in the surrounding area from records with the U.S. Department of Defense for a total of 522 gravity measurements at 374 separate stations. The field gravity measurements were reduced to complete Bouguer and residual gravity anomalies and plotted using standardized techniques. A gravity survey over an alluvial basin provides a tool that enables the determination of the volume of ground water stored in a basin. This is accomplished through the calculation of anomalous mass, or mass deficiency in the case of sedimentary basins, from the plot of residual gravity. The second part of this paper involves the development of a water budget for the Camas Creek drainage basin. Finally, the hydrologic parameters derived in this investigation are compared with those from previous studies, and the discrepancies are discussed.

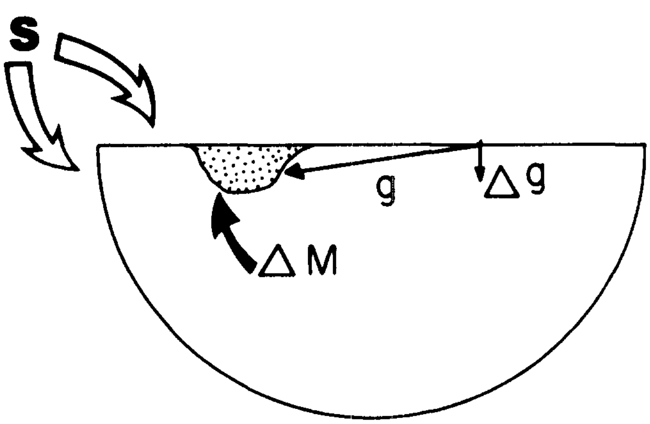

Fig. 3. The application of Gauss's theorem to determine the anomalous mass of a sedimentary basin. See text for explanation of symbols. (From West and Sumner, 1972.)

GROUND-WATER VOLUME HELD IN THE STORAGE BASIN

Theoretical Basis of Calculation

A determination of mass deficiency, representing saturated pore space, can be obtained by applying Gauss's theorem to a residual gravity anomaly map (Hammer, 1945). The theorem for a gravitational field is

$$-4\pi GM = \iint g \cdot \delta s \qquad (1)$$

where g is the gravitational field vector caused by a mass distribution of mass M; δs is an elemental surface vector on a closed surface S of arbitrary shape that completely surrounds the mass distribution; and G is the gravitational field constant. The total flux of g out of the surface S is $-4\pi GM$. By Hammer's method, a hemisphere encloses the mass M and is oriented with the spherical surface below the mass, and the planar surface above the mass (Figure 3). The level surface of the earth is represented by the upper planar surface.

In the case of a sedimentary basin, the enclosed mass is an anomalous mass ΔM which is the result of the density contrast between low-density alluvium and high-density bedrock. However, there is no need to consider the density differences or body dimensions since the surface integral of the normal component of gravity (Δg) can be used to calculate the enclosed mass. If the hemisphere is large, equation (1) may be integrated so that gravity can be measured over the upper planar surface, which represents the Earth's surface. The integral of equation (1) is:

$$2\pi G\Delta M = \iint \Delta g(x,y)\delta x\, \delta y \qquad (2)$$

The anomalous mass (ΔM) of a sedimentary basin can be found by integrating the gravity effect $\Delta g(x,y)$ over the upper plane. Davis (1967) described a method for calculating the surface integral of equation (2). On a residual gravity anomaly map, a square grid template is superimposed, and at each grid point ($\delta x\, \delta y$) the value of the residual gravity anomaly is read and summed to

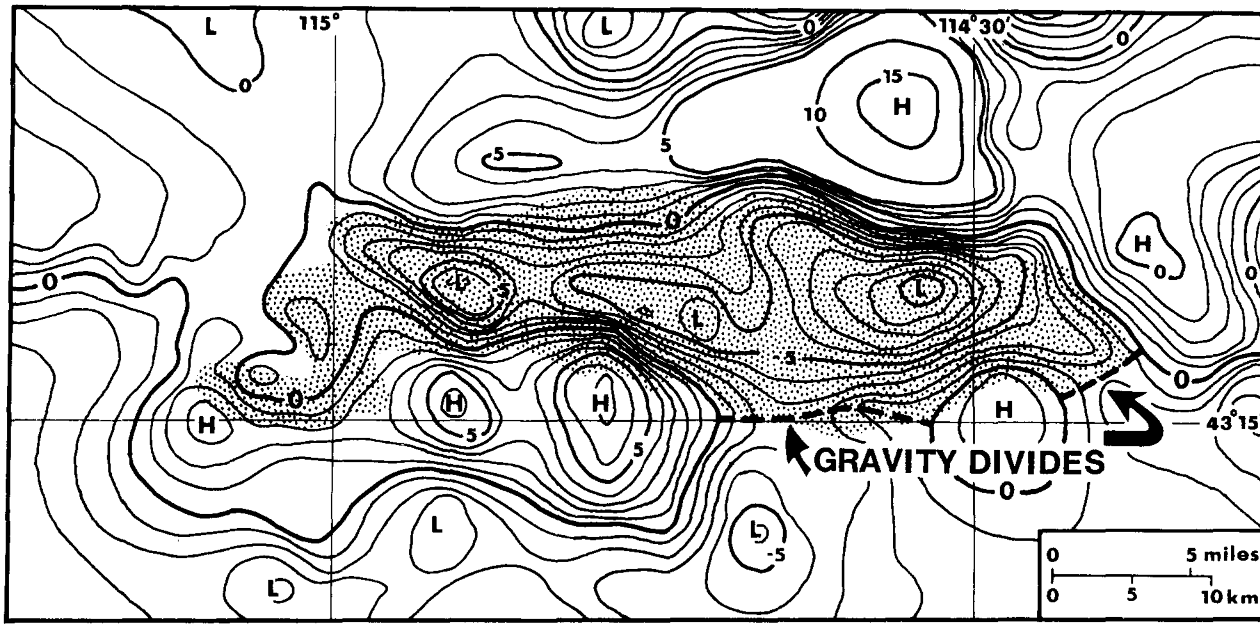

Fig. 4. Residual gravity anomaly map of the Camas Prairie. H and L are anomalous highs and lows, respectively. Residual values were calculated from the complete Bouguer gravity anomaly plot by passing the grid through a band pass filter. In this operation all gradients with wavelengths greater than 50 km are subtracted. Shaded area shows general outline of the Camas Prairie sedimentary basin (compare to Figure 2). Contour interval 1 mGal. Modified from Cluer, 1987.

give a numerical approximation of the surface integral.

Application of Method

The method of determing the anomalous mass, as described above, was applied to the Camas Prairie basin. A transparent template with a one km^2 grid was placed on the residual gravity anomaly map (Figure 4). At each node ($\delta x, \delta y$) on the grid, the residual gravity anomaly value was read (directly, or interpolated if between isogals), and the sum of all values was multiplied according to equation (2). The limit of the surface integral is the 0 mGal isogal of the residual anomaly map, which closely parallels the basin margins. Where gravity divides occur (in the Mount Bennett Hills south and southeast of Macon Flats, see Figure 2) the 0 mGal isogal was closed by crossing the divides (see Figure 4). The value of the surface integral obtained by this method is $-4.7952(10^{16})$ grams.

Interpretation

A negative anomalous mass, or mass deficiency, is measured in the Camas Prairie because the basin-filling materials are less dense than the surrounding igneous and volcanic rocks. The density contrast is due to pore space in the basin fill. Since the mass deficiency is due to pore space, and pore space is filled with water (below the water table), the mass deficiency can be related to the volume of ground water held in the basin (West and Sumner, 1972).

In a previous application, the southwestern United States, depth to the water table was an important parameter to be estimated. In the Camas Prairie basin, however, the water table is either above the surface, or less than one meter below the surface, for several months in spring and summer. The assumption that the water table equals the surface is made for the following calculations.

Anomalous mass of water may be converted to volume, since volume (V) is equal to mass (M) divided by density (Γ).

$$V = M \div \Gamma$$

In this case the mass deficiency M is known and is due to a density contrast caused by pore space in the alluvial material, and the pore space is assumed to be completely saturated with water (water density = 1 g/cm^3). Thus:

$$V = 4.7952(10^{16})\text{g} \div 1\ \text{g/cm}^3 = 4.7952(10^{16})\text{cm}^3$$

Converting from cm^3 to km^3 then:

$$V = 4.7952(10^{16})\text{cm}^3 \div 1(10^{15})\text{cm}^3/\text{km}^3 =$$

$$47.952\ \text{km}^3\text{, or } 38.9 \text{ million ac-ft}$$

of water held in pore space in the Camas Prairie storage basin.

Now that the volume of water held in pore space within the Camas Prairie basin has been approximated, the volume and average thickness of porous material can also be estimated. Using porosity data (from Davis, 1969) and estimating average porosity of basin fill reported in 76 drill logs on the Camas Prairie, the volume of porous material (potential aquifer volume) is about 320 km^3 at 15% average porosity. Because the area within the 0 mGal isogal on the Camas Prairie floor is 562 km^2, it follows that the average thickness of porous basin filling material is approximately 0.57 km (1800 ft). The basement of the Camas Prairie is probably not flat, rather it may appear trapezoidal or triangular in cross section, so the aquifer thickness would be two to three times greater [1 to 1.5 km (3000 to 5000 ft)] in the center of the basin and thinner near the margins.

A related study involved two-dimensional modeling of the basin subsurface along north-south gravity profiles (Cluer, 1987). The models indicate that tectonic displacement of the basin floor is up to 3 km (9500 ft) and the basin is filled with approximately 1.7 km (5400 ft) of porous alluvium at its center. Aquifer thickness estimates derived from the anomalous mass determination agree with the findings in two-dimensional gravity modeling.

Previous estimates of basin depth and associated aquifer thicknesses have been made by Piper (1926) and Walton (1962). Both considered the Camas Prairie basin to be not more than 0.3 km (1000 ft) in maximum depth. Because the deepest borehole on the Camas Prairie did not bottom on bedrock at 0.37 km (1200 ft), the greater basin depth estimates of this paper are supported.

Volume of Available Ground Water

Specific retention is that proportion of water not available by pumping, due to adhesion of water to sediment particles. That portion of the volume of water that drains from a saturated medium due to the attraction of gravity is the specific yield. Because tests to determine specific yield of materials in the Camas Prairie have not been conducted, a range of representative values based on data given in Johnson (1972) were used to estimate upper and lower limits of water quantity available from storage in the Camas Prairie basin.

A review of 76 well logs from the Camas Prairie indicates that the upper 0.15 km (500 ft) of basin fill is composed of 40-45% sand- to gravel-sized material, and 55-60% silt-sized and/or smaller material. If it is assumed that these proportions are generally representative of the entire body of basin-filling sediments, theoretical ground-water yield may be estimated. Table 1 presents a range of ground-water yield that may be expected from the Camas Prairie basin.

Table 1. Ground Water Available from Storage in the Camas Prairie Basin (Specific Yield Data from Johnson, 1972)

Material	*Specific yield %*			*Volume 10^6 ac-ft*
Sand and gravel (coarse)	maximum	35		13.61
	minimum	10		3.89
	average	24		9.34
Silt and clay (fine)	maximum	19		7.39
	minimum	0		0.0
	average	9		3.50
Mix of 40% coarse and 60% fine			maximum	9.88
			minimum	1.56
			average	5.83
Mix of 45% coarse and 55% fine			maximum	10.19
			minimum	1.75
			average	6.13

Calculations of available ground water from storage are based on 38.9(10^6) ac-ft of water held in pore space, and a range of values for specific yield. The average specific yield for the two basin-fill mixtures calculated (based on well logs, lower half of Table 1) suggests that approximately 6(10^6) ac-ft of ground water may be available for consumption from storage in the Camas Prairie basin.

BASIN WATER BUDGET

Calculating a ground-water mass budget for a drainage basin is an effective way to discover unknown aquifer boundaries. A first step in such analysis is to compute the parameters of a water budget:

$$\text{Inflow} = \text{Outflow} \pm \text{Changes in Storage} \qquad (3)$$

This equation is a simple statement of mass observation, what goes in must come out. Changes in storage may be neglected if the other variables in equation (3) are analyzed over a long period (i.e., 20 or more years), and that is the case in this study.

Inflow

Local precipitation in the forms of rain and snowfall are the sole sources of water input to the Camas Creek drainage basin. Currently, three precipitation recording stations and seven snow courses in the basin are maintained by government agencies and individuals. A summary of records currently available for the precipitation recording

Table 2. Precipitation Data for Stations on the Camas Prairie*

Station name	*Elevation (feet)*	*Record period years*	*Annual rainfall (inches)*
Manard	5020	1963-1985	14.68
Hill City	5080	1961-1980	14.80
Fairfield	5065	1962-1985	17.31

* Sources: US Weather Service; USDA Forest Service; C. Frostenson.

stations is provided in Table 2. Table 3 presents snow course records for stations within and surrounding the Camas Creek drainage basin. Although data collection was initiated as early as 1895, uninterrupted records for all locations begin shortly after 1960.

In a mountainous area that receives a large percentage of its total annual precipitation as snow, it is necessary to integrate precipitation and snow course records to establish the total water input to the drainage basin. Since snow courses indicate only the amount of water held in storage at any given time, the problem is to separate annual precipitation from monthly snow accumulation. To solve this problem, snowpack and annual precipitation were compared in order to derive annual precipitation from snow course records. Two of the snow course stations are equipped with Snotel electronic recording devices. This instrument is capable of recording snowpack and individual precipitation events, continuously, through all seasons. A relation was derived between annual precipitation and snow accumulation at the two Snotel locations and applied to other snow courses with similar geographic locations in order to estimate annual precipitation from monthly snowpack.

Table 3. Snow Course Data Within or Near the Camas Creek Drainage Basin

Station elevation/period	*Mean monthly water equivalent (in inches)*			
	February	*March*	*April*	*May*
Camas Creek Divide 5710 ft/1962-1985	INC	10.60	10.20	N/A
Soldier Ranger Station 5740 ft/1958-1985	9.50	11.60	10.60	INC
Bennett Mountain 6560 ft/1960-1985	12.90	15.20	18.10	11.20
Couch Summit 6840 ft/1947-1985	13.20	16.70	18.80	14.20
Dollarhide Summit 8420 ft/1961-1985	17.20	20.90	25.40	25.00

Notes: INC = incomplete data set; N/A = records not available.

Source: USDA Soil Conservation Service.

Table 4. Estimated Water Equivalents for Snow Course Stations (inches)

Location	*Months Summed*	*Sum*	*Conversion factor*	*Annual precipitation**
Camas Creek Divide	March, April	20.8	1.05	19.81
Bennett Mountain**	March, April	33.3	1.05	31.71
Soldier Ranger Station	Feb., March	21.1	0.99	21.31
Couch Summit	Feb., March	29.9	0.99	30.20
Dollarhide Summit**	Feb., March	38.1	0.99	38.49

* Annual precipitation = Sum ÷ Conversion factor.
** denotes Snotel control station.

At the Bennett Mountain Snotel site, it is noted that since 1960, the sum of March and April snowpack nearly equals annual precipitation. The relationship between the two values is then:

$$CF = (\text{March} + \text{April snowpack}) \div \text{annual precipitation} \tag{4}$$

where CF is the conversion factor derived by dividing the sum of March and April snowpack by annual precipitation. At Bennett Mountain, the conversion factor is 1.05. Similarly, a relationship exists between February plus March snowpack and annual precipitation at the Dollarhide Summit station (CF = 0.99). The result of applying these observed relationships to the other snow courses in the drainage basin is presented in Table 4.

Typically, in water budget studies, isohyetal maps are prepared which depict zones of differing precipitation and illustrate various local effects on precipitation caused by elevation, topography, rain-shadows, orographic effects, etc. Recording station density in the Camas Creek drainage basin is, however, inadequate for construction of a detailed isohyetal map. Nonetheless, Tables 2 and 4 indicate that there are four ranges of precipitation values different enough to allow estimation of precipitation amount by area, on the basis of elevation.

In ascending elevation, the approximate isohyetal regions are: (1) the area below 5200 ft, with an average of 15.60 in. annually; (2) the area between 5200 ft and 6000 ft, with 20.56 in. annually; (3) the area between 6000 and 8000 ft,

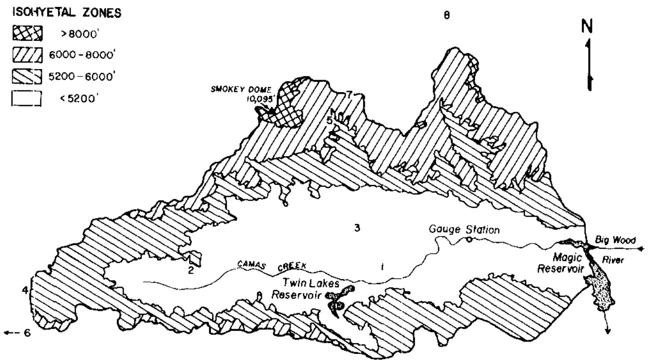

Fig. 5. Map of topography controlled theoretical isohyetal zones. Numbers are locations of recording stations: 1–Manard; 2–Hill City; 3–Fairfield; 4–Camas Creek Divide; 5–Soldier Ranger Station; 6–Bennett Mountain (located west of number, as indicated by arrow); 7–Couch Summit, and 8–Dollarhide Summit. Precipitation measurements are given by zone in text.

with 30.96 in.; and (4) the area above 8000 ft, with 38.50 in. of annual precipitation. These data are presented in Figure 5.

Using the total area of 742 miles² in the Camas Creek drainage basin, precipitation amounts for the four areas are calculated and summarized in Table 5. Total annual precipitation in the Camas Creek drainage basin is calculated at $8.54(10^5)$ ac-ft, by the method outlined above. Sources of possible error in these calculations are as follows.

1. Topographic effects are pronounced in theoretical isohyetal zones 2, 3, and 4. Because the planimetered areas are map area rather than true surface area, measured areas in these three mountainous zones are up to 30% less than actual surface area.

2. Precipitation records for the mountainous regions are based on snow course measurements, and represent calculated annual precipitation based on only two winter months.

3. Orographic precipitation, or summer thunderstorms, are a common occurrence in isohyetal zones 2, 3, and 4. Measures of this precipitation are not available for locations except where Snotel equipment is installed.

The author believes that the above listed potential errors act to reduce the estimated total precipitation figure. Thus, total annual precipitation of $8.54(10^5)$ ac-ft is conservative, and may represent only a portion of the actual value.

Table 5. Estimated Annual Precipitation for Each Isohyetal Region of the Camas Creek Drainage Basin

Isohyetal region	*Elevation (feet)*	*Area (mi.²)*	*Precipitation (inches)*	*Total precipitation (10^5 ac-ft)*
1	<5200	320	15.63	2.67
2	>5200 <6000	271	22.64	3.27
3	>6000 <8000	141	31.75	2.39
4	>8000	10	38.50	0.21
Totals		742		8.54

Outflows

Only one stream, Camas Creek, exits the drainage basin, flowing east down the axis of the Camas Prairie to its confluence with the Big Wood River at Magic Reservoir. A stream gauge station 4.2 km (2.6 mi.) upstream of the high water level at Magic Reservoir has been operated since 1912. The average discharge, calculated over the period from 1944 to 1984, is $1.39(10^5)$ ac-ft/yr (U.S. Geological Survey, 1985). Peak discharge is typically during middle to late April.

A second parameter on the loss side of the mass-balance equation is evapotranspiration (ET). The Blaney-Criddle method of calculating ET (Blaney and Criddle, 1962) is applicable in this situation since all variables either have been recorded, or can be estimated or extrapolated from nearby areas. The principal assumption is that ET varies directly with the sum of the products of mean monthly air temperature and monthly percentage of daytime hours, when adequate soil moisture is present. Thus, the solution is considered potential (or maximum) ET for irrigated cropland. The formula used is

$$U = kf \tag{5}$$

where $f = tp \div 100$; and U is estimated ET (consumptive use) for the growing season. Blaney and Criddle list monthly percentage of daytime hours (p) and a consumptive use coefficient (k) for various crop types. Mean monthly air temperature values (t) are available from the U.S. Weather Service, and have been averaged for the past 25 years.

Table 6 presents ET estimates using the Blaney-Criddle formula [equation (5)] and the consumptive use coefficeint for irrigated alfalfa, the greatest water-consuming crop (by type and area) on the Camas Prairie. By reducing the growing period and consumptive use coefficient, it is possible to estimate ET for nonirrigated cropland also. The typical period required for dry-land alfalfa to mature on the Camas Prairie is 45 days, although a limited amount of regrowth is common after the first harvest, but only over a portion of

Table 6. ET Estimates for Irrigated Alfalfa, 90-Day Period (See Text for Definition of Terms)

	½ May	*June*	*July*	*½ August*
p	5.11	10.38	10.50	4.87
t	50	56	66	63
k	0.85	0.85	0.85	0.85
tp/100	2.56	5.81	6.93	3.07
U	2.18	4.94	5.89	2.61

ΣU = 15.62 inches

Table 7. ET Estimates for Nonirrigated Alfalfa, 60-Day Period (See Text for Definition of Terms)

	½ May	*June*	*½ July*
p	5.11	10.38	5.25
t	50	56	66
k	0.75	0.75	0.75
tp/100	2.56	5.81	3.47
U	1.92	4.36	2.60

ΣU = 8.88 inches.

the area. This is approximated by an additional 15 days in the growing period. Table 7 reflects these estimates.

Presently there are 18,000 acres irrigated, and 87,000 acres of dry cropland on the Camas Prairie (U.S. Department of Agriculture, 1987). It follows that ET for irrigated cropland is $2.34(10^4)$ ac-ft for the growing season, or approximately 100% of the annual precipitation over that cropland (see Figure 5, isohyetal zone 1) by the Blaney-Criddle method. Similarly, ET for nonirrigated cropland is $6.44(10^4)$ ac-ft, or 57% of the annual precipitation over that cropland (all cropland is in isohyetal zone 1).

In a similar mass-balance study, Walton (1962) calculated a water budget for the Camas Creek drainage basin in an attempt to estimate the amount of recharge to the artesian aquifer. Walton balanced the mass equation by estimating surface runoff and recharge from standard percolation tables, then subtracting the sum of these two values from estimated mean precipitation. The residual value in this calculation was then considered to be equal to ET. Walton's use of the water-balance equation yields an estimated 11 in. of ET, from 17 in. of precipitation, or an ET rate of 65%.

Summing the empirical dry-land and irrigated ET calculations in the Camas Prairie (by the Blaney-Criddle method, used in this investigation) yields an ET rate of 64%, approximately the same ET percentage used by Walton. Because the results of both methods are similar, 65% ET is assumed to represent a reasonably accurate figure for all cropland on the Camas Prairie, and is the base value used to compute ET for other vegetation types and isohyetal zones in the basin. The remaining area of the Camas Creek drainage basin is primarily rangeland and forest vegetation types, where ET is not well understood anywhere (Sokolov and Chapman, 1974).

Table 8. ET Values Related to Isohyetal Zones of Figure 5

Zone	*Area ($mi.^2$)*	*Precipitation (10^5 ac-ft)*	*ET rate (%)*	*Total ET (10^5 ac-ft)*
1 cropland	164	1.37	65	0.89
(residual)	156	1.30	50	0.65
2	271	3.27	50	1.64
3	141	2.39	50	1.20
4	10	0.21	50	0.11
Totals	742	8.54		4.49

The 65% ET rate for cropland seems excessive when applied to forest or rangeland in the Camas Creek drainage basin, as the latter are higher in elevation, average several degrees cooler, and have a much shorter growing season. An arbitrary ET rate of 50% was chosen for rangeland and forest areas in the basin. Following the ET rates are annual ET calculations for individual precipitation zones, presented in Table 8. Total annual ET for the Camas Creek drainage basin is $4.42(10^5)$ ac-ft.

Completing the annual water balance calculations then:

$$8.54(10^5)(\text{inflow}) - [1.39(10^5)(\text{stream Q}) + 4.42(10^5)(\text{ET})] = 2.73(10^5)\text{ ac-ft}$$

Thus, $2.73(10^5)$ ac-ft of water is not accounted for by the mass conservation equation [equation (3)]. Hence, there is a large excess or residual in the water budget that must exit the Camas Prairie basin as underflow.

DISCUSSION

Underflow of $2.73(10^5)$ ac-ft/yr calculated in this study is over 10 times greater than $2(10^4)$ ac-ft estimated by Walton (1962). His estimate was based on a theoretical study of flow through a cross section, of the known aquifer, defined by ground-water potential surface contours obtained from measurements at existing wells. This potential surface map indicates a ground-water divide in the vicinity of Magic Reservoir, between the 1537 and 1530 m (5,040 and 5,020 ft) isopiestic contours (see Walton, 1962; Plate 1). There the hydraulic gradient is 4.5 m/km (23 ft/mile), and the cross section is approximately 20 km (12 miles) wide. He computed underflow using the formula (from Ferris, 1951):

$$Q = TIL \tag{6}$$

where Q is discharge; T is transmissibility; I is the hydraulic gradient; and L is the aquifer width. Walton's estimate of underflow assumes that: (1) the basin is shallow [150 to 300 m (500 to 1000 ft)]; and (2) the ground-water divide is coincident with the surface-drainage divide at Magic Reservoir.

During the record drought year of 1977, Young (1978) conducted a study to determine the effects of increased ground-water pumping in the Camas Prairie aquifer. He determined that pressure heads in the artesian aquifer declined between 1 and 4 m (3 and 14 ft) from 1974 to 1977. Young also "refined" mean annual ground-water recharge estimates by measuring stream losses, and concluded that Walton's figure of $4(10^4)$ ac-ft was a good estimate.

It is believed by this author that the static water table [and perhaps the artesian aquifer(s)] of the Camas Prairie is above permeable strata in the Mount Bennett Hills. Although the Mount Bennett Hills define a surface drainage divide, they are composed of permeable materials such as ash-flow tuffs, vesicular basalt, and sand and gravel lenses. Numerous flow contacts and highly jointed basalt flows also contribute to the overall transmissivity of the Mount Bennett Hills. This hypothesis is also supported by geologic cross sections developed through gravity modeling (Cluer, 1987). Two areas of negative anomalous mass are evident in the Mount Bennett Hills, south and southeast of the Macon Flats basalt flow (see Figure 2 for location with respect to geology, between semicircular positive anomalies, Figure 4), by nonclosure of the 0 mGal isogal. These two areas on the residual gravity anomaly map may be indicative of buried porous (permeable?) volcanic and/or alluvial materials (ground-water divides) that may act as a conduit for underflow. However, even areas of positive gravity anomalies in the Mount Bennett Hills are permeable and may serve as underflow pathways if below the water table.

Although underflow is the most ambiguous variable in the water mass-balance study, it is a possible transport mechanism responsible for very large volumes of ground water exiting the Camas Prairie storage basin, and may explain the discrepancy in the water-balance computations between this and previous investigations. The underflow and recharge values in previous reports are both one order of magnitude smaller than the figures calculated in this study. Finally, if there are no long-term changes in the storage volume (and that is assumed here), recharge must be equal to ET plus underflow. Comparing recharge values of this report to previous reports, recharge to the Camas Prairie basin is $7.15(10^5)$ versus $4(10^4)$ ac-ft annually.

CONCLUSIONS

The determination of anomalous mass deficiency indicates that there is a large volume of porous material in the Camas Creek basin, and that the volume of ground water held in storage is approximately 39 million ac-ft. This indicates that there are more, larger, or deeper aquifers in the basin than previously recognized. Of the total volume, specific yield of the basin-filling materials is estimated at 6 million ac-ft, or 15% of the total ground water. These values could be refined by applying site-specific porosity and grain density measurements, both of which could be obtained from boreholes in the basin-filling materials of the Camas Prairie.

Although the mass-balance estimates presented in this paper should be considered preliminary, they indicate that ground-water flux in the Camas Creek drainage basin is much more dynamic than previously believed. The volume of water leaving the basin by underflow is substantial [approximately $2.73(10^5)$ ac-ft/yr], and far in excess of previous estimates. Similarly, recharge to the basin (the difference between precipitation and ET) is greater than $7(10^5)$ ac-ft/yr, compared to $4(10^4)$ ac-ft/yr in previous studies. The bulk of ground water leaving the Camas Creek drainage basin by underflow may be transported through the two gravity divides, possible ground-water divides, on the southeast and eastern margins of the basin. Because underflow is a function of recharge, ET, and precipitation and the values of all these parameters in this and previous studies are estimates, they should be confirmed by installing equipment that will measure such parameters in the various elevation and vegetation zones throughout the Camas Creek drainage basin.

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REFERENCES CITED

Armstrong, R. L., J. E. Harakal, and W. M. Neill. 1980. K-Ar dating of the Snake River Plain (Idaho) volcanic rocks-new results. Isochron/West. no. 27, pp. 5-10.

Armstrong, R. L., W. P. Leeman, and H. E. Malde. 1975. K-Ar dating, Quaternary and Neogene volcanic rocks of the Snake River Plain, Idaho. American Journal of Science. v. 275, pp. 225-251.

Blaney, H. F. and W. D. Criddle. 1962. Determining water requirements in irrigated areas from climatological and irrigation data. U.S. Department of Agriculture, Soil Conservation Service, Technical Paper 96.

Cluer, B. L. 1987. A gravity model of basement geometry and resulting hydrogeologic implications of the Camas Prairie, south-central Idaho. Unpublished Northern Arizona University M.S. thesis.

Cluer, J. K. and B. L. Cluer. 1986. The late Cenozoic Camas Prairie Rift, south-central Idaho. Contributions to Geology, University of Wyoming. v. 24, no. 1, pp. 91-101.

Davis, R. W. 1967. A geophysical investigation of hydrologic boundaries in the Tucson basin, Pima County, Arizona. Unpublished University of Arizona Ph.D. dissertation.

Davis, S. N. 1969. Porosity and permeability of natural materials. In DeWeist, R.J.M., ed., Flow Through Porous Media. Academic Press, New York, NY.

Ferris, J. G. 1951. Ground water, chap. 7. In Wisler, C. O. and E. F. Brater, eds., Hydrology. John Wiley and Sons, New York. pp. 198-272.

Hammer, S. I. 1945. Estimating ore masses in gravity prospecting. Geophysics. v. 10, pp. 50-62.

Johnson, E. E. 1972. Ground Water and Wells. Johnson Division, Universal Oil Products Company, St. Paul, MN.

Kirkham, V.R.D. 1931. Snake River downwarp. Journal of Geology. v. 39, pp. 456-482.

Leeman, W. P. 1982. Geology of the Magic Reservoir area, Snake River Plain, Idaho. In Bonnichsen, B. and R. M. Breckenridge, eds., Cenozoic Geology of Idaho. Idaho Bureau of Mines and Geology, Bulletin 26. pp. 369-376.

Mitchell, J. C. 1976. Geothermal investigations in Idaho, Part 7, Geochemistry and geologic setting of the thermal waters of the Camas Prairie area, Blaine and Camas Counties, Idaho. Idaho Department of Water Resources, Water Information Bulletin. no. 30, 44 pp.

Piper, A. M. 1926. Ground water for irrigation on Camas Prairie and Elmore Counties, Idaho. Idaho Bureau of Mines and Geology, Pamphlet 15. 46 pp.

Sokolov, A. A. and T. G. Chapman. 1974. Methods for Water Balance Computations; An International Guide for Research and Practice. The Unesco Press.

Struhsacker, D. W., P. W. Jewell, J. Zeisloft, and S. H. Evans. 1982. The geology and geothermal setting of the Magic Reservoir area, Blaine and Camas Counties, Idaho. In Bonnichsen, B. and R. M. Breckenridge, eds., Cenozoic Geology of Idaho. Idaho Bureau of Mines and Geology, Bulletin 26. pp. 377-393.

U.S. Department of Agriculture. 1987. Idaho cooperative river basin study, Camas Creek erosion and sediment study. 116 pp.

U.S. Geological Survey, Water Resources Division. 1985. Idaho water year 1984. Great Basin and Snake River Basin above King Hill, ID-84-1. v. 1.

Walton, W. C. 1962. Ground-water resources of Camas Prairie, Camas and Elmore Counties, Idaho. U.S. Geological Survey Water-Supply Paper 1609. 57 pp.

West, R. E. and J. S. Sumner. 1972. Ground-water volumes from anomalous mass determinations for alluvial basins. Ground Water. v. 10, no. 3, pp. 24-32.

Young, H. W. 1978. Water resources of Camas Prairie, south-central Idaho. U.S. Geological Survey, Water-Resources Investigations 78-82, Open File Report. 34 pp.

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