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COMMENTARY

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Let's Talk About Dead Pool: How We Discuss the Shallows of Reservoirs

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Key Points:

- The term "dead pool" is being used differently by researchers, water managers, and journalists. We aim to clarify and nuance its meaning
- Critical reservoir elevations are more complex than they sound due to operational decisions, infrastructure change and water temperatures
- Reservoir storage decline manifests in at least three ways: terminally, seasonally, or temporarily

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Abstract The term "dead pool" has been circulating in water resources discourse in multiple ways, prompting confusion about what it means. In this commentary, we aim to clarify the definition of dead pool (and related terms describing critical reservoir elevations) to encourage clearer conversations about reservoir storage decline going forward. We also make two arguments to animate future research about the shallows of reservoirs. First, we suggest that critical reservoir thresholds such as dead pool are better thought of as dynamic and multifaceted rather than as static and singular elevations. Second, we offer a typology that aims to distinguish among three different types of reservoir storage decline. Taken together, a shared vocabulary about reservoir levels and a more nuanced conceptualization of how reservoirs shrink can better situate water scholars and policymakers to understand and manage reservoirs in an era of water overuse and climate change.

Plain Language Summary Extreme lows in reservoirs haven't always been a major topic of conversation in water resources research, but climate change and drought are changing that. Here we take stock of the language that is being used to describe critically low elevations in reservoirs in an effort to reduce terminology mix-ups in these emerging conversations. We also make two arguments to enliven future research about the shallows of reservoirs. We argue that critical reservoir levels are actually more dynamic and complicated than they sound, and also that reservoirs shrink to extreme lows in different ways that should be distinguished from one another. Our overall aim is to make conversations about critical reservoir elevations more productive by making it easier for researchers, journalists, and decision-makers to understand each other and pose new questions.

1. Introduction

As the disparity between water demand and supply has worsened in the Colorado River Basin, a previously little-used water management term—"dead pool"—has been showing up in all sorts of places. The phrase has appeared in national headlines about the visibly shrinking Lake Powell and Lake Mead (Arkin, 2022; White, 2023), in glossaries for publics now attuned to Colorado River dynamics (AZDWR, 2022), and in reservoir operations research (Huizar et al., 2023; Turner et al., 2022). This attention is a good thing. We should be talking about reservoir storage decline under current water management regimes and a changing climate. However, dead pool conversations have been accompanied by confusion about what the term actually means, stoked mainly by the fact that different water interlocutors have deployed it in different ways (Glennon, 2022).

The first goal of this commentary is to clarify the meaning of dead pool (and related terms) to encourage clearer conversations about critical reservoir elevations. If scientists, policy-makers, and journalists want to better plan for—and avoid—dead pool, we need shared terminology. In addition, we point to global examples of reservoir decline to highlight the relevance of this topic (Table 1) (To be clear, we are not arguing that the established engineering definition of dead pool be revised, but that public discourse around it be sharpened). We then make two conceptual arguments to animate future scholarship. We suggest that critical reservoir thresholds are better thought of as dynamic and multifaceted rather than as static and singular elevations, and we offer the beginnings of a typology to distinguish different types of reservoir storage decline. We focus on examples from the western United States because that region's low reservoirs have received extensive attention from media and researchers.

2. The Term "Dead Pool" Is Used to Mean Different Things

Taking a step back, it is remarkable that distinguishing among extremely low levels within reservoirs has become necessary in some places—including at the two largest reservoirs in the United States (Lake Powell and Lake

Table 1
Differing Usages of the Term "Dead Pool" in Recent Studies of Low Reservoirs (News Articles Are Cited in the Absence of Scientific Literature)

Location of low reservoir(s)	Citations	Is "dead pool" used to mean the reservoir elevation below which water can no longer be released?
Brazil		
Cantareira water supply system, São Paulo	Deusdará-Leal et al. (2020)	Yes
Chile		
Nine reservoirs in central Chile	Fernández et al. (2023)	Yes
Ghana		
Volta Lake/Akosombo Dam	Ayivor and Ofori (2017); Han and Webber (2020)	Term not used
Bui Reservoir/Dam	Cartey (2021) (news article)	Term not used
Spain		
Mequinenza Reservoir	Gualtieri (2022) (news article)	Term not used
Turkey		
Demirkopru Reservoir	Gorguner et al. (2020)	Yes
USA—California		
13 reservoirs	Tarroja et al. (2016)	No, describes minimum power pool
Central Valley	Tarroja et al. (2019)	No, describes minimum power pool
Entire state	Dogrul et al. (2016)	Yes
	Dogan et al. (2018)	Unclear
USA—Kansas		
Cedar Bluffs Reservoir	Birkowski (2008)	Yes
USA—Colorado River Basin		
Lake Mead and/or Lake Powell	Barnett and Pierce (2008)	Yes
	Barsugli et al. (2009)	Yes
	Hansen et al. (2022)	Yes ("dead storage")
	Huizar et al. (2023)	Yes
	Meko et al. (2012)	Yes
USA—Texas		
J.B. Thomas Reservoir	Rohli et al. (2023)	Unclear
Big Cypress-Sulfur Basin	Weintraub et al. (2017)	Yes
USA—Western states	Turner et al. (2022)	No, describes minimum power pool
USA—Continental	Steyaert and Condon (2024)	Yes

Mead), along with others worldwide (Table 1). With that in mind, *of course* the terminology used in public discourse is still being refined.

So what is "dead pool"? That depends on who you ask. Two definitions have been afoot in public discourse. For some, including many journalists, dead pool is the reservoir elevation at which hydropower production is no longer possible (e.g., Booth, 2021; Sakas, 2022). For others, including many water managers, dead pool describes the point at which a reservoir can no longer release water at all (e.g., AZDWR, 2022). In other words, water managers reserve the term "dead pool" to demarcate the lowest pool in a reservoir, which lies below the reservoir's outlets. When talking about the limits to hydropower production, water managers employ the term "minimum power pool" instead (Glennon, 2022).

The discrepancy between journalistic and managerial uses of "dead pool" may have something to do with courting public attention. After all, minimum power pool is the nearer of the two thresholds at Powell and Mead, so it has garnered the most press, and the word "dead" makes for a more dramatic headline. But critiquing the media for

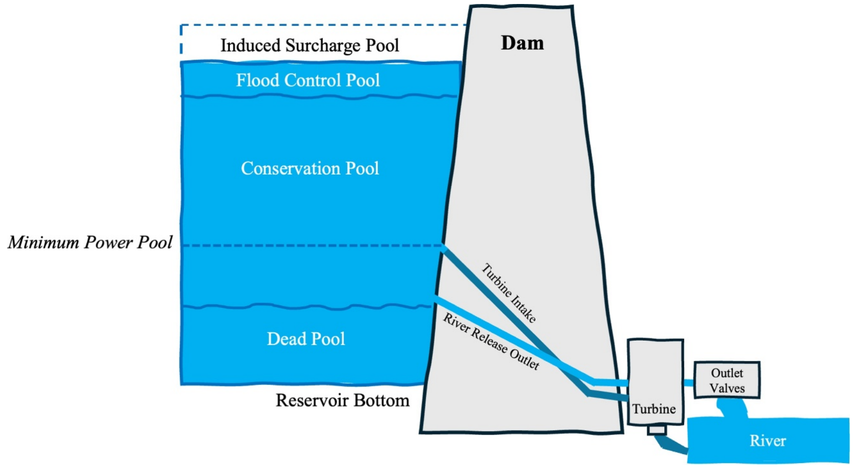

Figure 1. A simplified reservoir schematic showing four operational zones (or "pools") and two outlets: one for hydropower generation and one for non-power releases. In some reservoirs, these outlets are distinct, creating separate minimum power pool and dead pool levels; in others, a single outlet serves both. For context, other pools in this generic reservoir include the induced surcharge pool, kept empty for extreme flooding events; the flood control pool, empty during flood-prone months; and the conservation pool, which holds water for many purposes that may include tribal water contracts, irrigation, municipal supply, hydropower production, environmental flows, and more.

sensationalism ignores other reasons the term might be leveraged this way. For instance, some journalists and researchers specialize in energy and therefore see reservoir dynamics through the lens of hydropower (e.g., Kennedy, 2022; Tarroja et al., 2016; Tarroja et al., 2019; Turner et al., 2022). Moreover, prominent institutions have used dead pool to refer to hydroelectric viability (e.g., UNEP, 2024). In other cases, the definition is unspecified or the term goes unused (Table 1).

There are finer points to the confusion between dead pool and minimum power pool as well. Agencies manage reservoirs for different purposes, and these objectives are reflected in their vernaculars. In the United States, the U.S. Army Corps of Engineers (USACE) focuses on flood control, while the U.S. Bureau of Reclamation (USBR) emphasizes irrigation. The agencies' official glossaries reflect these priorities. Given the USACE's focus on *full* reservoirs, its central glossary includes many terms associated with flooding but none for reservoirs' lower limits (USACE-SD, 2024). The USBR, on the other hand, includes "dead storage" and "top of inactive capacity" in its official dictionary, but not "minimum power pool" (USBR, 2022).

The definitional challenges do not end there. USACE acknowledges that the nomenclature used to demarcate distinct pools in its reservoirs vary by district (USACE, 2018, pp. 2–2). Indeed, though USACE's central glossary does not describe reservoirs' lower limits, the agency's Southwestern Division offers a fact sheet that explains "inactive pool" as being the hydropower generation minimum (USACE, 2024). Different agencies also calculate reservoir storage in different ways—sometimes including a reservoir's "dead pool" in the total, sometimes not (Hansen et al., 2022). Add to this the fact that dams, reservoirs, and power plants come in many physical configurations—with implications for what makes storage "live" or "dead"—and the complexities multiply. The idiosyncrasies are so numerous that the Utah Department of Natural Resources warns researchers against mixing reservoir data from different sources (Utah Department of Natural Resources, n.d.).

When it comes to parsing reservoir levels, the more specific the terminology, the better for knowing what it does and does not mean. In keeping, we recommend sticking to water managers' typical phrasing, in which "minimum power pool" is used to describe the bottom of a reservoir's hydropower-producing capacity and "dead pool" applies to the elevation at which water can no longer be released from a reservoir by gravity alone. We illustrate this recommended terminology below (Figure 1).

3. Critical Reservoir Elevations Are Not as Straightforward as They Sound

Minimum power pool and/or dead pool are typically assigned precise elevations, and these fixed numbers reverberate through public discourse about water. For example, discussions of Lake Powell put its minimum power pool at 3,490 feet above sea level (1,064 m) and its dead pool at 3,370 feet (1,027 m) (USBR, 2024a). Reservoir modelers must also establish a lower bound in their models, and often set 10% of storage capacity as the threshold (Wada et al., 2014). Conceptualizing extremely low reservoir elevations with a specific height is useful for modeling—and reservoirs have real design thresholds that cannot be ignored—but singular and static levels may also be too simple a schema, for at least three reasons.

First, from an operational standpoint, minimum power pool is more of a *range* than a single point. For example, at Lake Powell, dam operators would modify Glen Canyon Dam hydropower operations, or even halt them, before reaching the reservoir's minimum power pool elevation of 3,490 feet. Indeed, in 2021 and 2022, when Lake Powell was still 35 feet above its minimum power pool, the Bureau of Reclamation made unprecedented moves to bolster the reservoir's elevation, per guidelines set out in official reservoir management plans (UCRC, 2019; USBR, 2023). In other words, while Lake Powell's official minimum power pool is 3,490 feet, changes to reservoir operations kicked in at 3,525 feet, stretching the operational signature of minimum power pool across a range of 35 feet.

Second, changing infrastructure conditions have implications for critical reservoir elevations, and they will need to be worked into conceptualizations of these levels when or if they manifest. For example, critical reservoir thresholds might effectively be raised if sediment shrinks storage volumes or impacts water outlets (Randle et al., 2021; Yao et al., 2023), or if outlet works face other technical problems, such as at Glen Canyon Dam (Fleck, 2022; USBR, 2024b) and at Amistad Dam on the Rio Grande River (IBWC, 2024). Going further, some entities have sought to build new reservoir outlets at low points not previously thought necessary, which changes water access at extremely low elevations. For example, water agencies in Nevada recently dug a new water intake from Lake Mead at 1,000 feet (SNWA, n.d.).

Finally, water temperatures also play a role in defining critical reservoir elevations (Null et al., 2024; Olden & Naiman, 2009; Zarri et al., 2019). Reservoirs that have temperature-regulating obligations may need to adjust operations to protect a cold water pool even at elevations above minimum power pool or dead pool. The upshot of these examples is that, for water managers, critical reservoir thresholds may be more dynamic and multifaceted than is implied by the fixed thresholds that circulate in public discourse and models. This is yet another potential zone for misunderstanding that can be avoided with explanation and care.

4. Not All Critical Reservoir Elevations Are Made the Same

Studies of reservoirs globally (B. Wang et al., 2024; Z. Wang et al., 2024; Yao et al., 2024) and in the United States reveal a consistent negative trend in reservoir storage (Adusumilli et al., 2019; Hou et al., 2022; Randle et al., 2021; Simeone et al., 2024; Steyaert & Condon, 2024; Zhao & Gao, 2019). Within this trend lie many complexities. For example, some reservoirs are on a steady trajectory toward critically low elevations, while others hit them predictably and quickly bounce back. Still others get low only during bad droughts and take a few years to rebound. Recent reservoir modeling studies that leverage the new ResOpsUS data set corroborate these dynamics (Simeone et al., 2024; Steyaert & Condon, 2024; Steyaert et al., 2022).

This variation in how critical reservoir elevations manifest—and how long they last—suggests that not all dead pools or minimum power pools are made the same and that researchers would benefit from developing categories that nuance our conversations about shrinking reservoirs. We sketch out the beginnings of such a typology here with three rough categories: *terminal*, *seasonal*, and *temporary* reservoir storage decline (Figure 2). These categories partially map onto a helpful set of reservoir classifications offered by Simeone et al. (2024) in a recent analysis of U.S. reservoir decline—within-year, over-year, and highly variable reservoirs—but diverge in a few ways (Using minimum power pool as an example: Our *terminal* category partly maps onto the *over-year* reservoirs in Simeone et al. (2024), but not all *over-year* reservoirs will experience *terminal* minimum power pool. Our *seasonal* category and their *within-year* category are a good match; both describe reservoirs with cyclical and seasonal lows. However, our *temporary* category diverges from Simeone et al. (2024)'s *highly variable* category because theirs mainly includes flood control reservoirs in the eastern U.S. that see unpredictable peaks due to flood flows and we are focused on reservoirs that see sporadic and extreme lows for a few years due to drought/climate).

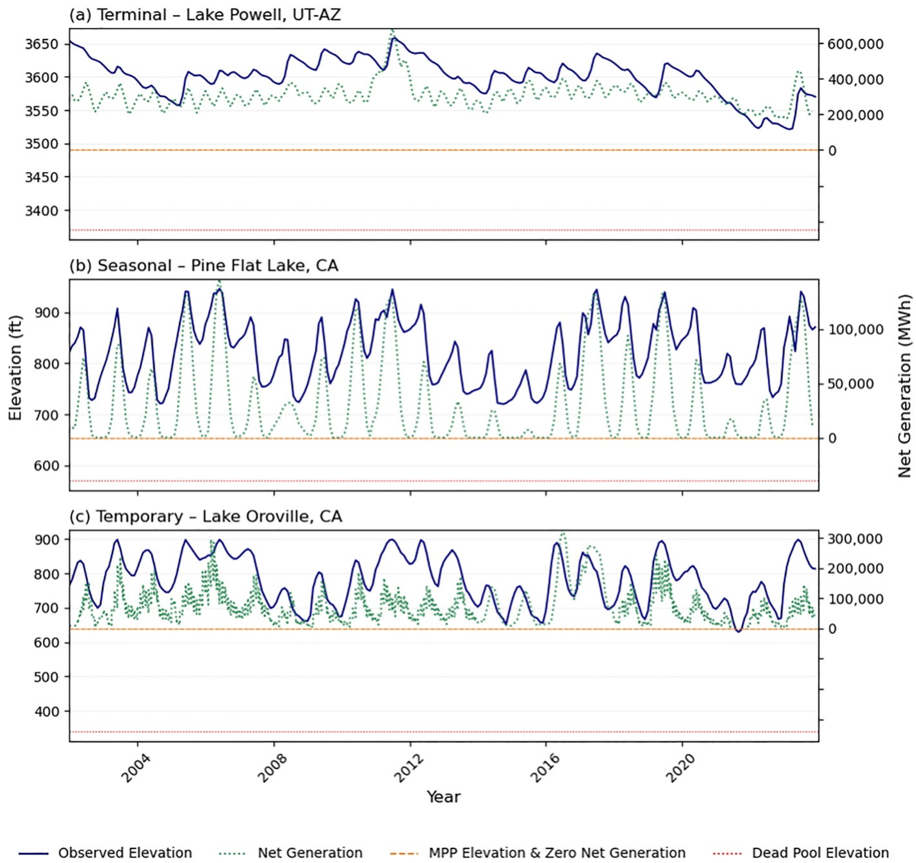

Figure 2. Reservoir elevation time series from 2002 to 2023 showing three types of elevation dynamics: (a) *terminal* decline at Lake Powell (UT-AZ), (b) *seasonal* fluctuations at Pine Flat Lake (CA), and *temporary* drought-related decline at Lake Oroville (CA). The dashed yellow line indicates the minimum power pool threshold and zero net generation, and the red dashed line marks the dead pool threshold specific to each reservoir. A secondary *y*-axis shows monthly net hydropower generation (dotted green line).

4.1. Terminal Reservoir Storage Decline

Lakes Powell and Mead are both very large reservoirs that show strong linear negative trends in storage over multi-decadal time scales. These reservoirs stand apart from others because they are steadily falling toward critically low elevations, and have been for decades (Simeone et al., 2024; Steyaert & Condon, 2024). The descent is the result of a chronic imbalance between outflows (kept high by the Colorado River Compact) and inflows (shrinking due to climate change–related aridification and extended drought) (Overpeck & Udall, 2020; Williams et al., 2022). One or both these reservoirs could become *terminal* cases of minimum power pool or dead pool without substantial changes in water use.

4.2. Seasonal Reservoir Storage Decline

By contrast, other reservoirs regularly reach low elevations and recover quickly. These reservoirs tend to be smaller and receive abundant inflows. They are also known as "within-year" storage reservoirs—as opposed to "over-year" reservoirs, which take more than a year to fill (Vogel et al., 1999). At these reservoirs, which are common throughout the western U.S., periods of extremely low storage are "frequent but short," and are part of seasonal patterns (Simeone et al., 2024). An example is the Pine Flat Reservoir in California. Pine Flat often gets too low for hydropower production because agricultural water deliveries are top priority and shrink the reservoir to below the operational range of the power plant's turbines (personal communication, KRCD, 2023) (Water temperatures and dissolved oxygen levels can also limit hydropower production). At Pine Flat, arriving at minimum power pool is unsurprising and short-lived (and may be ameliorated by a forthcoming low-flow turbine; KRCD, n.d.).

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4.3. Temporary Reservoir Storage Decline

Another category of reservoirs fits somewhere in between *terminal* and *seasonal* reservoir storage decline. These are rarer cases of reservoirs that dwindle to critically low levels infrequently and temporarily—typically during severe droughts. For example, a shrunken Lake Oroville in northern California hit minimum power pool and ceased hydropower production for several months in 2020–2021 (CDWR, 2021), as well as in 1976–1977 (Turner et al., 2022). In both instances, Lake Oroville recovered within a few years: its 2021 episode reversed by mid-2023, after a "snow deluge" replenished storage (CADWR, 2023; Marshall et al., 2024). In cases like this, critical reservoir lows are neither terminal nor seasonal. Instead, they are a multi-year event that occurs generationally, during the very worst droughts.

These forms of reservoir storage decline have different impacts and implications—and they get varying levels of media and policy attention. *Terminal* storage decline may be the worst-case variety, since the steady decline of a large reservoir has broad implications for water supply over many years and the regional power grid. Recovery from *terminal* decline also requires difficult trade-offs in water allocation. By contrast, *seasonal* arrivals at low reservoir elevations are less impactful and more predictable. Finally, *temporary* storage declines are bound to be locally disruptive to water and energy resources, and may impact wider areas, but the instances of these lows are so far limited in number, geographic extent, and duration. In any of these cases, the impacts of critical reservoir lows will be felt by all users of a reservoir: not just hydropower users, but also tribes, ecosystems, irrigators, cities, recreators, navigation, etcetera. The impacts to each set of stakeholders will vary, however, based on how they are positioned in the legal and regulatory hierarchy of reservoir operations and whether they have alternative sources of water.

5. Future Research

We expect that the term "dead pool" will remain salient in water resources research and public discourse, though hopefully with clearer and more nuanced usage. If water scholars—and our counterparts in media and policy—want to understand, manage, and potentially limit reservoir storage decline, we need shared terminology. For the sake of precision, we align with water managers by recommending that dead pool be used to describe the very lowest pool in a reservoir—the water that cannot be released downstream because it sits below the outlet works—and that minimum power pool be used to describe the point at which hydropower can no longer be produced.

With a common vocabulary in place, future researchers can set about asking more interesting questions than "what is dead pool"? A crucial next step is formalizing the typology of reservoir storage decline that we offer here, and posing questions that could inform policy. For example, in the case of *terminal* storage decline in the Colorado River reservoirs, will water cuts being made and contemplated (USDOI, 2022) be enough to stave off critical reservoir lows in the short and long terms (B. Wang et al., 2024; Z. Wang et al., 2024, preprint)? When it comes to *seasonal* reservoir decline such as that at Pine Flat Reservoir, how can water and energy users predict and adapt to those periods? Or when it comes to *temporary* minimum power pool per Lake Oroville, can researchers pinpoint the conditions under which it manifests, and what a rebound requires? Moreover, how are different water users impacted by these reservoir lows and their varied manifestations, and what could water managers and policy-makers do to assuage those diverse impacts?

Finally, future research would do well to expand the geography of these inquiries—and our policy conversations. As scholars of water in the western U.S., we have situated this commentary in that region's reservoirs, but water storage has fallen below target thresholds elsewhere in the U.S. (Johnson, 2023; Patterson & Doyle, 2018; TVA, 2017; Valdez, 2025), as well as internationally (Table 1). We hope that shared terminology will make it easier for researchers and decision-makers who are raising questions about the shallows of reservoirs to connect across disciplines, regions, and continents.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

No new data were collected or created for this research.

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Erratum

The originally published version of this article contained a typographical error. Coauthor Eleanor Andrews's name was incorrectly presented as Elanor Andrews. The error has been corrected, and this may be considered the authoritative version of record.