Concerns Regarding Increased Nutrient Loading Proposed for the use of Wastewater Effluent for Snowmaking at the Snowbowl Facility on The San Francisco Peaks, Arizona

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11/30/21

PREFACE

The Arizona Snowbowl facility located in the San Francisco Peaks of Northern Arizona has been the subject of controversy since issuance of a Special Use Permit (SUP) from the U.S.D.A. Forest Service over eighty years ago. Initial protests related to the imposition on the religious and cultural integrity claimed by several Tribes who hold the San Francisco Peaks as sacred and of substantial religious and cultural significance. The cases which arose from these protests were consistently rejected by the courts, with the Supreme Court in 1979 determining that the findings of the lower courts should hold. This allowed expanded development of recreational facilities to proceed, although not without continued protests. When the use of treated wastewater effluent was approved as a result of the 2005 Final Environmental Impact Statement (FEIS) and the subsequent Record of Decision (ROD), the basis of protest expanded beyond cultural and religious issues associated with Indigenous Peoples, to include concerns with human health and environmental degradation—recognizing that these all are in fact related issues.

In summary, the decision to approve and permit implementation of Alternative #2[1] as described within the FEIS, which includes the use of wastewater effluent for snow making, represents a significant disruption of material and energy flows associated with

[1] ALTERNATIVE #2 Per FEIS

- Approximately 205 acres of snowmaking coverage throughout the SUP area utilizing Class A reclaimed water as a source.
- A 10 million-gallon snowmaking water reservoir near the top terminal of the existing Sunset Chairlift, and catchment pond below the Hart Prairie Lodge.
- Construct a reclaimed water pipeline between Flagstaff and the Snowbowl with booster stations and pump houses.
- Construct a 3,000 to 4,000 square foot snowmaking control building in the vicinity of the existing maintenance shop.
- A professionally designed and managed snow play/tubing facility at the base area including sculpted lanes, lifts and a lodge.
- Replace of the Sunset Chairlift with a high speed, detachable chair.
- Relocate the existing Sunset Chairlift as the Humphreys Chairlift, accessing a pod of proposed ski trails.
- Upgrade and extension of the Hart Prairie Chairlift with a high-speed, detachable lift.
- Upgrade and realignment of the Aspen Chairlift.
- Install three surface conveyors in the area north of the Hart Prairie Lodge.
- Install a handle tow is proposed to service a halfpipe and terrain park.
- Additional terrain, bring total skiable acreage at the Snowbowl to approximately 204 acres
- Approximately 47 acres of thinning to created improved glades.
- Approximately 87 acres of terrain improvements (grading/stumping and smoothing).
- Create a dedicated teaching area near the Hart Prairie Lodge.
- Construct a halfpipe.
- Enlarge the Hart Prairie Lodge by approximately 6,000 square feet to a total of 24,900 square feet.
- Construct a new 10,000 square foot guest services facility adjacent to the Agassiz Lodge.
- Construct a 2,500 square foot Native American cultural and education center constructed in or near the Agassiz Lodge
- Replace existing on-mountain ski team buildings.
- Construct a 14.8-mile pipeline to transport reclaimed water from Flagstaff to Snowbowl.
- Install snowmaking pipelines buried within existing and proposed trails.
- Redesign the entrance circle, which would have signs directing guests to parking lots, day lodges, and snow play parking.
- Construct a 400-space parking area to service the proposed tubing facility.
- Combine parking lots #1 and #2 by re-grading and leveling them.
- Develop approximately 1,110 feet of additional on-mountain access road.
- Reconstruct approximately 3,650 feet of existing two-track mountain access road.
- Decommission approximately 3,050 feet of existing two-track mountain access road/
- Install buried 10,000-gallon water storage tanks at each of the lodges and at the snow play building to facilitate the use of reclaimed water.
- Construct a pedestrian underpass

the long-established stability of the ecology of the region, including ecosystems contiguous to the facility, such as the Hart's Prairie Grasslands, and possibly to even more remote systems.

The complexity of the dynamics of surface and groundwater flows and attendant nutrients and minerals is recognized within the FEIS as not being well understood[2], and yet within the FEIS the stated presumption is *"that overall benefits of providing stable winter recreational opportunities for the public and community…. merit its (Alternative #2) selection."* Furthermore, it is stated that selecting Alternative #2 meets the purpose and need *"to provide consistent and reliable operating season and to improve safety, skiing conditions, and recreational opportunities by bringing terrain and infrastructure into balance with existing demand."*

It is not clear what is meant by terrain. It could be that this is a surrogate word for ecosystem. There is similar ambiguity with the use of the word balance. Typically, balance would imply a dynamic equilibrium in which internal processes maintain equality between inputs and outputs. In this case however it might mean a compromise between disruptive anthropogenic influences and historical ecological stability. The presumption appears to be that these disruptions do not seriously impose upon the ecological stability of the region, and yet support for such presumption is eroded by statements of uncertainty in groundwater and associated solutes movement, as noted in footnote 2, and by field evidence of polluted runoff being discharged off site during heavy rainfall periods as delineated within the reportmprepared and issued by Richard Hereford

To reiterate, the presumption that Alternative #2 would sustain a balance between this terrain and the recreational opportunities is not well supported within the FEIS text, particularly in the movement of excess water associated with heavy rainfall and snow melt, and with wastewater effluent associated with snowmaking and the various components carried by the effluent, including the nutrients nitrogen and phosphorus as well as mineral loads associated with typical wastewater. In addition, the introduction of impervious infrastructure areas, such as parking lots and new buildings, combined with increased visitation, can be expected to decrease the time of concentration and increase maximum surface discharge rate while degrading the quality of runoff associated with stormwater, and hence interfere with the pre-development rapid rate of seepage into the permeable volcanic sediments as well as with the rates of transmission and retainage of nutrients and minerals.

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[2] From FEIS: *"The patterns of groundwater movement in the perched aquifers are complex; groundwater movement in these perched systems do not necessarily coincide with the topographic divides for surface water flow; and the divides for groundwater movement are complex and likely change in response to annual variations in the amount and distribution of snowmelt in the Hart Prairie watershed. Due to the complex movement of groundwater through the surficial deposits and underlying volcanic deposits in this area, it is not presently possible to precisely project where snowmelt infiltrated from upslope areas flows in the downgradient Hart Prairie watershed….Due to the complex movement of groundwater through the surficial deposits and underlying volcanic deposits in this area, it is difficult to specifically determine the sources of shallow groundwater for the perched aquifers in the Hart Prairie area. Therefore, the degree to which any change in groundwater availability or water quality resulting from implementation of Alternative 2 actions would impact the wells, springs, and stock tanks in this area cannot be projected with certainty."*

It has been observed and documented that discharge of surface runoff to downgradient watersheds, e.g., Harts Prairie Grasslands, occurs during heavy storm events. There is a real possibility that this runoff includes reclaimed water from snowmelt associated with the ski slopes, as well as septic tank seepage and eroded soils. A detailed reporting of such occurrences, dated October, 2021, is included in a field study directed by Richard Hereford, research geologist--Documented Stormwater Runoff Beyond Arizona Snowbowl's Permit Area Causes Erosion and Pollution of Hart's Prairie Ecosystem.

Within this report it is noted that off-site discharge of substantial stormwater runoff was observed during two 2021 events, one in April and one in July. The April event was associated with snowmelt, while the July event was primarily the result of rainfall. Runoff at rates of up to 21.7 cubic feet per second were noted to have moved beyond the limits of the SUP boundary into the region of the Hart's Prairie Grasslands. This runoff carried with it heavy sediment and nutrient loads, as well as trash and other debris. This discharge outside the SUP boundary, if it contained components of reclaimed water, is in violation of the Arizona Department of Environmental Quality -- Water Quality Standards

R18-9-704:

G. Prohibited Activities

(3) misapplying reclaimed water for any of the following reason:

c. allowing runoff of reclaimed water or reclaimed water mixed with stormwater from a direct reuse site.

Within this report entitled Concerns Regarding Increased Nutrient Loading Proposed for the use of Wastewater Effluent for Snowmaking at the Snowbowl Facility on The San Francisco Peaks, Arizona, dated November 2021, is offered detailed comparative evaluation of nutrient loads (nitrogen and phosphorus) for pre-development and post-Alternative #2 conditions. The loading increase is significant for both nutrients with Alternative #2, far exceeding the calculated historical loading, and suggestive that perturbations of this magnitude could render the nutrient dynamics far from a nearly equilibrium state. And while within the FEIS it is recognized that:

> *"the addition of snowmaking to operations at Snowbowl would result in an overall increase in moisture and nutrients and may change plant species composition within the SUP area. Proposed snowmaking is likely to add 31.1 lb/acre/yr of nitrogen over historic natural deposition. This may increase the dominance of early successional or weedy plant species. In turn, this may reduce overall plant diversity in some portions of the SUP."*

This is conditioned by a presumption that:

"…however, this effect would be restricted to developed ski trails and therefore localized."

There presently is insufficient reason to justify this presumption. To effectively assess the ecological impact of the disruption to the hydrologic and nutrient loading dynamics associated with Alternative #2 upon the Arizona Snowbowl SUP area as well as contiguous and downgradient areas, a more extensive evaluation is required. It is recommended that this issue be further evaluated by experts in Systems Ecology and the behavior of complex systems supported by additional, well designed field investigations, as well as the input from indigenous peoples with expansive, multi-generational knowledge of the San Francisco Peaks.

INTRODUCTION AND REVIEW OF CONCERNS

Ecosystems typically establish their collection of naturally selected species through an evolutionary process known as succession. When environmental conditions stabilize within a consistent range of fluctuations over an extended period, the successional process will trend towards a quasi-steady state, meaning the balance of material and energy inputs and outputs are maintained through active internal processes. The collections of species within the steady state ecosystem adapt to this range of fluctuations and adjust accordingly to sustain steady state and ensure a high level of stability. In their paper Chemostasis and Homeostasis in Aquatic Ecosystems , Stumm and Stumm-Zollinger[3] note that *"steady state is one of minimum entropy production (least free energy dissipation) compatible with external constraints upon the system (e.g., fixed concentrations or affinities in the environment) …. (*with*) well-known stability against external perturbations because a state of minimum entropy production cannot leave this state by a spontaneous irreversible change. If as a result of some fluctuation it deviates slightly from this state, internal changes will take place and bring back the system to its stable state."*

Stable ecosystems, which are said to be in a mature or climax state, rely upon the establishment of a quasi-steady state in which production (P) matches respiration (R), and hence there is minimal Net Ecosystem Production (NEP)—i.e., accumulation of excess biomass when P>R. The ability to maintain this stability through adjustments to a range of environmental fluctuations associated with the successional history of the system is known as homeostasis. Consequently, the rate of change over time approaches zero, and allows the system to persist over long periods of time.

The San Francisco Mountain is the result of volcanic activity within the San Francisco Volcanic Field with the last eruption of the mountain occurring about 400,000 years

[3]Stumm, W.R. and E.H. Stumm-Zollinger (1971) Chemostasis and Homeostasis in Aquatic Ecosystems; Principles of Water Pollution Control IN: Nonequilibrium Systems in Natural Water Chemistry; Hem, J.; Advances in Chemistry; American Chemical Society: Washington, DC, 1971.

ago[4]. The most recent volcanic activity within the Field was at the nearby Sunset Crater about 1,000 years ago. While the eruption of Sunset would be expected to have at least a short-term impact on the ecosystems associated with the San Francisco Mountain, an eventual return to historical environmental conditions supported the repair of any short-term consequences of this perturbation and reclamation of the previous ecological stability. However, regardless of the influence of the Sunset eruption, the ecosystems associated with the San Francisco Mountain have, as a minimum, had close to one thousand years to achieve a quasi-steady state.

In his book "The End of Certainty" Ilya Prigogine[5] introduces the concept of systems "Far-From-Equilibrium" in which "*new processes set in and increase the production of entropy"* and the system *"becomes unstable at some critical distance from equilibrium."* At this point the system seeks another path to recover stability, which results in significant changes. In summary, as noted by Prigogine, distance from equilibrium becomes an essential parameter in describing nature. Near equilibrium fluctuations are harmless, but "Far-From-Equilibrium" fluctuations are critically influential to system changes, and the exact nature of these changes becomes unpredictable. H.T. Odum[6] explained these disruptions as resulting in reduction in system maturity, which drives the ecosystem into a younger developmental stage of higher net productivity and of decreased complexity and stability, e.g., agricultural monocultures.

Consequently, when systems in steady state such as the evolved ecosystems associated with the San Francisco Mountain, are disrupted by extensive anthropogenic inputs, such as wastewater used for snowmaking, as well as disturbances from clearing, invasive species, escalating levels of atmospheric carbon dioxide, increased traffic activity, and installation of septic tanks and drainfields, the systems can be expected to move towards a "Far-From-Equilibrium" status, as these additional materials and energy imposed by our technological society, can far exceed the successional experience of the established ecosystems, as will be presented further into this text.

There are many examples of the impact of such far reaching anthropogenic disruptions to the flow of materials and energy to established, stable ecosystems. Many of these impacts occurred despite previous environmental studies which suggested findings of no significant impact (FONSI). There are some highly publicized examples associated with Florida of which I am most familiar. For example, the Indian River Lagoon (IRL) on Florida's East Coast developed as a diverse estuarine ecosystem with a high value of natural resources. The IRL achieved quasi-steady state stability over a successional period of 5,000 to 7,000 years following the stabilization of sea level and climate. Material inputs, particularly of the growth modulating nutrients, nitrogen and phosphorus were limited primarily to atmospheric deposition within a limited watershed, and some

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[4] Priest, S.S., W.A. Duffield, K. Malis-Clark, J.W. Hendley II and P.H. Stauffer. The San Francisco Volcanic Field, Arizona U.S. Geological Survey Fact Sheet 017-01
[5] Prigogine, I, 1997 The End of Certainty: Time Chaos and the New Laws of Nature The Free Press, New York, NY ISBN 0-684-83705-6
[6] Odum, H. T., Environment, Power and Society (1971) Wiley-Interscience, New York ISBN-13-978-0471652700.

interchange through tidal movement. Therefore, a paucity of biologically available nitrogen and phosphorus was a significant factor in the control of primary production and gave a selective advantage to emergent seagrasses which benefitted from the clarity of the overlying water column, which allowed high transmissivity of light, and the ability of seagrasses to efficiently extract nutrients from the sediments. Early into the twentieth century however extensive urbanization and agricultural development resulted in substantial increases in inputs of nutrients, with a fourfold increase in phosphorus loading and significant inputs of ammonia-nitrogen. While these loadings were initially relegated to the estuarine sediments, with time these sediment stores became exhausted and began to release these stored nutrients to the water column—what have become known as “legacy nutrients”. These legacy nutrients in combination with continued heavy nutrient loading from an expanded watershed have driven the ecosystem towards “Far-From-Equilibrium” conditions, which has resulted in a shift from seagrass dominance to phytoplankton dominance—including potentially toxic Cyanobacteria and Dinoflagellates[7]. In 2021 over 1,000 manatees died of starvation as they wintered in the IRL because of a 50% loss of seagrasses the previous year[8]. In addition, expansive fish kills have become problematic within the lagoon. The impact upon the local economy has been lower property values, reduced tourist activity, and potential threats to human health[9].

Similar stories are associated with other environmental features in Florida, including the replacement of native submerged grasses in Florida’s Springs with invasive benthic Cyanobacteria such as *Lyngbya sp.* as a result of extensive use of nutrient laden reclaimed wastewater and septic tank seepage[10]; the increased occurrence of Cyanobacteria within the 450,000 acre Lake Okeechobee as a result of “legacy” phosphorus[11]; the expansion of “red tide” organisms on Florida’s West Coast likely associated with nutrient releases from Lake Okeechobee[12]; and loss of scrub habitat attendant with widespread development, which has disrupted soil integrity and deleteriously impacted threatened species, including the Florida Scrub Jay[13].

Florida’s stories are similar to many documented throughout the nation, whether it is the problems in Toledo, Ohio from Harmful Algal Blooms (HAB) around the drinking water

[7] A 10-year Comprehensive Conservation and Management Plan for the Indian River Lagoon, Florida (2020) National Estuary Program www.irlcouncil.com

[8] Florida Fish and Wildlife Conservation Commission, Marine Mammal Pathobiology Laboratory 2021 Preliminary Manatee Mortality Table with 5-year summary 2/2/21 through 7/30/21

[9] http://blogs.ifas.ufl.edu/extension/2020/12/02/irl-fish-kill/

[10] Xueqing, G. (2008) TMDL Report Nutrient TMDLs for the Wekiva River (WBIDs 2956, 2956A, and 2956C) and Rock Springs Run (WBID 2967) Florida Department of Environmental Protection, Division of Water Resource Management, Bureau of Watershed Management Central District, Middle St. Johns Basin

[11] Missimer, T.M.; Thomas, S.; Rosen, B.H. Legacy Phosphorus in Lake Okeechobee (Florida, USA) Sediments: A Review and New Perspective. Water **2021**, 13, 39. https://doi.org/10.3390/w13010039

[12] https://calusawaterkeeper.org/news/algae-blooms-triggered-by-lake-okeechobee-releases-harm-wildlife-and-coastal-communities-7442/

[13] https://www.fws.gov/verobeach/msrppdfs/floridascrubjay.pdf

intake on Lake Erie[14]; the outbreak of Lyme's disease in the Northeast as a result of reduction of species predatory to the deer mouse[15]; or loss of soil and water quality within the Yellowstone National Park as attendant with elimination of the gray wolf[16]. Considering these and other developments, it is clear that the consequences of moving a stable ecosystem towards a "Far-From-Equilibrium" status are often severe, costly, and unanticipated.

The situation associated with the snowmaking alternative (Alternative #2) as delineated within the Final Environmental Impact Statement (FEIS) for Arizona Snowbowl Facility's Improvements[17] certainly deserves assessment in terms of the extent of disruption to the surrounding stable ecosystems, rather than a simple evaluation based upon subjective projections of impacts. This is particularly germane to the issue of increased nutrient and water loads, although other factors are also of concern, including the presence and influence of endocrine disruptors, metagenomics factors, synthetic organic contaminants, and other anthropogenic impositions.

The following section is centered around changes in the loadings and movement of additional loads of the nutrients nitrogen and phosphorus as compared to pre-development conditions, with implications regarding the extent of departure from steady state—i.e., how "Far-From-Equilibrium".

NUTRIENT ACCOUNTABILITY REVIEW

The potential influence of additional flows and nitrogen loads associated with proposed snowmaking (Alternative #2) is addressed within subsection 3H—Watershed Resources-- of the FEIS (pg. 3-160 to 3-224). Not included is any detailed discussion related to phosphorus other than soil content and leaching testing. Review of any nutrient loads associated with septic systems or the loadings from non-point sources is not included. The narrative on the nature and source of the wastewater effluent used for snowmaking is included in subsection 3G—Infrastructure and Utilities (pg. 3-150 to 3-159), but no discussion of phosphorus levels is included. Other subsections which provide information pertinent to the assessment of nutrient and hydrologic dynamics include 3I-Soils and Geology; 3J-Vegetation; 3K-Wildlife; and 3L-Geotechnical.

Within subsection 3H is a review of the groundwater dynamics associated with the 1,060.8-acre Snowbowl Sub-Area and the associated Hart Prairie Watershed and the Agassiz Sub-Watershed. The Snowbowl Sub-Area straddles the divide between these two, and is wholly contained within them, with most of the area within the Hart Prairie

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14 https://www.npr.org/sections/thetwo-way/2014/08/03/337545914/algae-toxins-prompt-toledo-to-ban-its-drinking-water

15 Levi, T, A.M. Kilpatrick, M. Mangel, and C.C. Wilmers (2012) Deer, predators, and the emergence of Lyme disease Proc Natl Acad Sci U S A. 10942–10947. Published online 2012 Jun 18. doi: 10.1073/pnas.1204536109PMCID: PMC3390851

16 https://www.yellowstonepark.com/things-to-do/wildlife/wolf-reintroduction-changes-ecosystem/

17 United States Department of Agriculture Forest Service Southwestern Region (2005) Final Environmental Impact Statement for Arizona Snowbowl Facilities Improvements, Volume 1 Coconino National Forest, Coconino County, Arizona

Watershed. The combined area of the 4,249.9-acre Hart Prairie Watershed and the 768.8-acre Agassiz Sub-Watershed is 5,018.7 acres.

The soils associated with the region are noted to be highly permeable, and consequently much of the precipitation and snowmelt is thought to recharge rather quickly into groundwater, with surface runoff being minimal. Recharged groundwater is noted to move vertically towards deeper aquifers but is impeded to some extent by lenses of confining silts and clay, which create intermittent, and often temporary perched conditions. These perched areas are important to maintenance of vegetation and wildlife. In some cases, this perched groundwater intersects with the ground surface creating springs and seeps. Within the FEIS it is made clear that there is considerable uncertainty regarding the nature and extent of groundwater flows, particularly those associated with these perched zones.

Analysis within the FEIS of the hydrological and water quality impact of snowmaking is limited to projections for wet, average, and dry season in terms of precipitation and snowmelt input as Acre-Feet (AF), evaporation and sublimation losses; Total Dissolved Solids (TDS); Total Organic Carbon (TOC); and Total Nitrogen (TN). These projections, summarized within Tables 3H-6 through 3H-8 of the FEIS, indicate that there is expected substantial increases in TDS, TOC, and TN concentrations within the groundwater during the dry season within the Snowbowl Sub-Area, with TN projected at 19.0 mg/L[18], well above the drinking water standard of 10 mg/L as Nitrate-N. Increases are not as severe with average and wet season projections, but still showing a doubling of TN and a tenfold increase in TDS during the average year.

In the FEIS discussion related to these projections it is suggested these increases are conservative (worst case) values, which do not account for retention within the soils, biological uptake, denitrification or additional commingling with other groundwater. The problem with the retention argument is the issue of long-term storage. If the soils are serving as nutrient stores, what is their storage limit and what happens when this limit is reached? This is how legacy nutrient conditions are established—by discounting the reality of conservation of mass. And while this could be countered by claiming extensive denitrification in the case of nitrogen dynamics, a substantial organic carbon source is required to facilitate denitrification. The rate and influence of the denitrification process was not evaluated within the FEIS, and was only mentioned once as a means of reducing nitrate levels.

It is noteworthy that movement of Nitrate-N from reclaimed effluent through groundwater has often proven problematic in terms of downgradient impact. For example, Nitrate from an effluent spray field owned and operated by the City of Tallahassee, Florida had

[18] The reported value as Total Nitrogen does not distinguish between Nitrate/Nitrite, Ammonia-N or organic-N. Effluent from a Bardenpho process—that used by Flagstaff Rio de Flagg facility—includes complete nitrification. As indicated in Table 3H-1 of the FEIS, most of the effluent nitrogen is as Nitrate-N.

profound impact upon the ecology of the downstream Wakulla Springs—a major tourist attraction—some fifteen miles away, resulting in lawsuits directed towards the city[19].

The comingling argument is a version of the *"dilution is the solution to pollution"* adage. A more comprehensive and meaningful approach to assessing influence of nutrient loading increases is to compare pre and post development nutrient inputs in addition to projecting long term rates of nitrogen within downgradient groundwater. This would provide nutrient accountability and offer further insight into the extent by which the associated ecosystem dynamics are driven from equilibrium.

For purposes of assessing nutrient dynamics, the initial study limits within this text will be the Snowbowl Sub-Area as well as the combined Hart Prairie Watershed and the Agassiz Sub-Watershed—5,018.7 acres. In a pre-development status, a major nitrogen input was likely atmospheric deposition and nitrogen fixation, as well as contributions from wildlife visitations. Phosphorus inputs would be primarily from atmospheric deposition and wildlife visitation to a lesser extent. The post-development (Alternative #2) nutrient input would be the sum of snowmaking from effluent; atmospheric deposition; nitrogen fixation; septic seepage; non-point sources, and wildlife visitation.

In the FEIS, atmospheric deposition is set at 0.50 mg/L Total Nitrogen, based upon records from the National Atmospheric Deposition Program (NADP)[20]. The review of NADP data from 1981 to the present for the Grand Canyon area indicates an annual average of 0.12 mg/l Ammonia-N and 0.14 mg/L Nitrate-N, or a Total Nitrogen, assuming no organic nitrogen is present, of 0.26 mg/L, somewhat lower than the FEIS value.

Atmospheric deposition of phosphorus was investigated from a number of sites around the world by Tipping et.al.[21]. They found the mean total phosphorus atmospheric loading rate at 0.027 g/m^2-yr, or 0.24 lb/acre-yr, or 256 lb/yr and 1,208 lb/yr Total Phosphorus for the Snowbowl Sub-Basin, and the Combined Hart Prairie/Agassiz for the Snowbowl Sub-Basin, and the Combined Hart Prairie/Agassiz respectively.

Hartley et. al[22] included nitrogen fixation ranges for the Colorado Plateau from 0.002 to 0.98 $nmol/cm^2$-hr under ideal conditions, which occur during limited periods during the year. They noted the areal fixation rate in drier environments could be as high as 35 kg/ha-yr or 31.3 lb/acre-yr. Within the FEIS nitrogen fixation is given as 15 kg/ha –yr, or 13.4 lb/acre-yr, which is commensurate with the literature. Fixation then is a major input source of nitrogen, amounting to about 14,215 pounds and 67,251 pounds of Total

[19] Davis, J.H, B.G. Katz, and D.W. Griffiin (2010) Nitrate-N Movement in Groundwater from the Land Application of Treated Municipal Wastewater and other Sources in the Wakulla Springs Springshed, Leon and Wakulla Counties, Florida, 1966-2018 USGS Scientific Investigation Report 2010-5099

[20] https://www.usgs.gov/water-resources/national-water-quality-program/national-atmospheric-deposition-program-nadp

[21] Tipping,E., S. Benham, J. F. Boyle, P. Crow, J. Davies, U. Fischer, H. Guyatt, R. Helliwell, L. Jackson-Blake, J. Lawlor, D. T. Monteith, E. C. Roweg and H. Tobermanac (2014) Atmospheric deposition of phosphorus to land and freshwater The Royal Society of Chemistry 2014 Environ. Sci.: Processes Impacts DOI: 10.1039/c3em00641g

[22] A. Hartley, N. Barger, J. Belnap, and G. Okin (2007) Dryland Ecosystems In: Soil Biology, Volume 10 Nutrient Cycling in Terrestrial Ecosystems P. Marschner, Z. Rengel (Eds.) © Springer-Verlag Berlin Heidelberg 2007

Nitrogen annually for the Snowbowl Sub-Basin, and the Combined Hart Prairie/Agassiz respectively over the study area. These rates are assumed to be applicable to both pre and post development conditions, although some disruption of nitrogen fixation dynamics as well as the rate of nitrogen output as denitrification may occur with the introduction of effluent. Often, nitrogen fixation is accomplished through symbiosis, and the captured nitrogen as ammonia-nitrogen is incorporated into plant biomass. It may be retained within long-term standing biomass or become part of the detrital food web, where it may again be recovered by the standing plant crop, be lost through denitrification, enter into the groundwater network, or sequestered within the soil matrix as refractory organic nitrogen. It is assumed that wildlife contributions (imports) of nutrients are offset by exports.

With the development of the Snowbowl Facilities, there is potential for some nutrient influx from runoff from impervious areas such as parking facilities, roads and roof structures. Typical nutrient loading rates for impervious land uses were estimated by Donigan et.al.[23] at about 11.7 lb/acre-yr for Total Nitrogen and 0.89 lb/acre-yr for Total Phosphorus. Considering the planned developments for Alternative #2 as delineated within the FEIS, there will be an estimated 4 acres of developed area, exclusive of the ski trails, which is typically in impervious urban/commercial /residential land use. The nitrogen addition from these non-point sources is rather modest at 46.8 lb/yr Total Nitrogen and 3.6 lb/yr Total Phosphorus for the combined study area. These values do not include increased runoff from the skiing trails during the warmer season, and it is possible that changes in the soil characteristics under these trails could result in increased sediment loads (erosional losses), as well as nutrient loads. Recent investigations into the nature of the runoff from disturbed areas indicate increased erosional loss does occur[24].

Nutrient inputs from the on-site septic system should also be included in the mass balance assessment. Recent septic tank studies in Florida provide indication that even following the drain field, septic tank effluent was as high as 50 mg/L Total Nitrogen and 6 mg/L Total Phosphorus[25]. With visitation to the proposed Alternative #2 Snowbowl Facility at about 3,000 persons during season, the water consumption is reported in the FEIS at about 1.5 million gallons annually, with most of this for restroom use. This would amount to 625 lb/yr Total Nitrogen and 75 lb/yr Total Phosphorus.

Using the hydrologic loadings for precipitation and snowmaking effluent, and effluent nutrient levels at 6 mg/L Total Nitrogen as reported in the FEIS and 3 mg/L effluent

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[23] Donigian, A.S., R.V. Chinnaswamy, P. N. Deliman (1998) Use of Nutrient Balances in Comprehensive Watershed Water Quality Modeling of Chesapeake Bay US Army Corps of Engineers Waterways Experiment Station, Technical Report EL-98-5

[24] Personal communications with Richard Hereford retired USGS Geologist

[25] Wekiva-Area Septic Tank Study (2018) Division of Environmental Assessment and Restoration, Florida Department of Environmental Protection 2600 Blair Stone Rd. Tallahassee, FL 32399 www.dep.state.fl.us

Total Phosphorus which would be a reasonable assumption for a 4-stage Bardenpho[26] effluent, a nutrient input assessment can be developed as shown in Table 1 for dry, wet and average season for the Snowbowl Sub-Area and the combined study area. It is noteworthy that while the increases in hydrologic loadings are minimal, the same is not true for Nitrogen and Phosphorus.

Table 1: Pre and Post Development (Alternate #2) Nutrient Inputs Snowbowl Sub-Area and Combined Hart Prairie/Agassiz Watershed

	Snowbowl Sub-Area						Agassiz + Hart Prairie					
	Pre-development Alternative			Post-Development Alternative #2			Pre-development Alternative			Post-Development Alternative #2		
	Average Season	Wet Season	Dry Season	Average Season	Wet Season	Dry Season	Average Season	Wet Season	Dry Season	Average Season	Wet Season	Dry Season
ACRES	1,061	1,061	1,061	1,061	1,061	1,061	5,019	5,019	5,019	5,019	5,019	5,019
Precipitation Acre-feet/yr.	2,892	4,408	1,190	2,892	4,408	1,190	12,498	19,051	5,144	12,498	19,051	5,144
Snowmaking Acre-feet/yr.	0	0	0	334	223	446	0	0	0	334	223	446
Percent increase in water inputs				**12%**	**5%**	**37%**				**3%**	**1%**	**9%**
NITROGEN INPUTS (lb.-N/yr.):												
Atmospheric Deposition	2,044	3,115	841	2,044	3,115	841	8,831	13,462	3,635	8,831	13,462	3,635
Nitrogen Fixation	14,215	14,215	14,215	14,215	14,215	14,215	67,251	67,251	67,251	67,251	67,251	67,251
Reclaimed Water	0	0	0	5,446	3,636	7,273	0	0	0	5,446	3,636	7,273
Septic	0	0	0	625	625	625	0	0	0	625	625	625
Non-Point Source	0	0	0	47	47	47	0	0	0	47	47	47
Total Nitrogen Input including N-fixation	***16,258***	***17,330***	***15,056***	***22,330***	***21,591***	***22,953***	***76,082***	***80,712***	***70,885***	***82,153***	***84,974***	***78,783***
Total Nitrogen Input excluding N-fixation	***2,044***	***3,115***	***841***	***8,115***	***7,376***	***8,739***	***8,831***	***13,462***	***3,635***	***14,903***	***17,723***	***11,533***
Percent increase including N-fixation				***37%***	***25%***	***52%***				***8%***	***5%***	***11%***
Percent increase excluding N-fixation				***297%***	***137%***	***939%***				***69%***	***32%***	***217%***
PHOSPORUS INPUTS (lb.-P/yr.):												
Atmospheric Deposition	256	256	256	256	256	256	1,208	1,208	1,208	1,208	1,208	1,208
Reclaimed Water	0	0	0	2,723	1,818	3,636	0	0	0	2,723	1,818	3,636
Septic	0	0	0	75	75	75	0	0	0	75	75	75
Non-Point Source	0	0	0	4	4	4	0	0	0	4	4	4
Total Phosphorus Input	***256***	***256***	***256***	***3,058***	***2,149***	***3,967***	***1,208***	***1,208***	***1,208***	***4,010***	***3,101***	***4,919***
Percent increase				***1095%***	***740%***	***1450%***				***232%***	***157%***	***307%***

[26] The four-stage Bardenpho process is intended to remove nitrogen through two stages of nitrification and denitrification, and is less expensive than a modified Bardenpho which includes additional units for phosphorus reduction. It is assumed Flagstaff uses the four-stage process, as phosphorus removal is not required by permit. As noted in Metcalf &Eddy Wastewater Engineering: Treatment, Disposal and Reuse 3rd Edition (1991) McGraw-Hill edited G. Tchobanoglous ISBN 0-07-041690-7 pg 670, effluent quality from an advanced wastewater treatment system using activated sludge + separate stages of nitrification and denitrification-- e.g., four-stage Bardenpho--the total phosphorus in the effluent ranges from 6-10 mg/L

DISCUSSION AND SUGGESTIONS

Offered is a cursory analysis regarding pre and post development nutrient balances and dynamics within the watersheds directly associated with and contiguous to the Snowbowl Facility. The indication that nitrogen and phosphorus loadings are notably increased with the use of wastewater effluent for snowmaking raises serious concerns related to ecosystem stability and uncertainty, which deserve additional consideration and study beyond the rather casual dismissal included in the FEIS—see quote below.

"the addition of snowmaking to operations at Snowbowl would result in an overall increase in moisture and nutrients and may change plant species composition within the SUP (Special Use Permit—which includes the Snowbowl Facility) *area. Proposed snowmaking is likely to add 31.1 lb/acre/yr of nitrogen over historic natural deposition. This may increase the dominance of early successional or weedy plant species. In turn, this may reduce overall plant diversity in some portions of the SUP; however, this effect would be restricted to developed ski trails and therefore localized."*

A mass balance analysis of the pre and post development conditions associated with the snowmaking Alternative #2 reflect an increase in nutrient inputs which could exceed the homeostatic capabilities of affected ecosystems. This analysis included both nitrogen and phosphorus, and it is not clear why phosphorus was not considered more relevant within the FEIS. (Phosphorus loading associated with Alternative #2 exceeded pre-development condition by over 700% in the Snowbowl Sub-Area and over 150% in the combined Hart Prairie/Agassiz watershed.) When such loadings are persistent and exceed that representative of the successional history of the associated ecosystems, conditions "Far-From-Equilibrium" conditions can be established, which can foment significant ecological disruptions. While typically unpredictable, changes may well include--but not limited to:

- Increased Net Ecosystem Production (NEP) as a result of high rate of primary productivity in response to increased nutrient availability.
- Provide selective advantage to invasive plant species, which can change soil characteristics; interfere with critical symbiotic relationships such as related to nitrogen fixation; and possibly render key species vulnerable to pests and pathogens.
- Changes in vegetative complexion can impact consumer species and disrupt critical Predator-Prey relationships.
- May impact the rate of herbivory if key predators are deleteriously impacted, which can change the complexion of primary production.
- Accumulation of excess biomass from increased NEP renders the systems more vulnerable to destructive fires.
- Loss of vegetative complexity and diversity may make the region more vulnerable to erosion.

- Loss of overall ecological diversity reduces overall homeostatic capabilities, adding to the uncertainty of future changes.
- Imposes upon available nutrient stores within the soils, which when eventually saturated can create a “legacy” situation, resulting in long scale internal nutrient releases.
- Transmission of nutrient loads through groundwater may impact downgradient ecosystems, such as the Hart Prairie Grasslands.

While it is suggested within the FEIS that the nutrients associated with the snowmaking process will impact only the local region around the skiing trails, this is inconsistent with claims also included in the FEIS that most of the water and associated nitrogen will quickly enter the underlying groundwater. It should be noted that discarding excessive nutrients into groundwater is typically not a solution, for eventually some if not most of this groundwater finds a surface outlet either as springs and seeps along the ground surface, or release into larger water bodies. In both instances these nutrients can become problematic. Admitting that the groundwater patterns within the region are complex and not well understood should give concern regarding the fate of these excess nutrients.

Like aquatic, estuarine and marine systems, which have received the most attention from the scientific community regarding eutrophication related to Harmful Algal Blooms (HAB) and serious fish wildlife and habitat loss, terrestrial systems such as those associated with the Snowbowl study area can also be disrupted by excessive nutrient loading. This is particularly true when these loads exceed that associated with the successional history of these systems. In such cases the homeostatic capabilities may be exceeded, and the system driven to a “Far-From-Equilibrium” situation. Over the long-term this can lead to changes which can be unpredictable and irreversible.

NITROGEN

Nitrogen loads as noted in Table 1 increase by 25% to 52% in the Snowbowl Sub-Area when effluent is used in snowmaking, dropping to a 5% to 11% increase in the combined study area. However, as nitrogen loads may impact the symbiotic relationships associated with nitrogen fixation, these increases need to be considered without the influence of fixation—resulting in an increase to 137% to 939% for the Snowbowl Sub-Area and 32% to 217% for the combined study area if nitrogen fixation is seriously disrupted.

Nitrogen within the Class A+ effluent used for snowmaking is expected to be largely as nitrate, which is a form readily available for biological uptake. As the amount of readily available nitrogen increases, the need for nitrogen fixation is reduced, and the nitrogen fixing plants could face a disadvantage. This could be particularly damaging to the sensitive Alpine Tundra in the upper reaches of the Snowbowl but could also impact downgradient grasslands and conifer forests.

Because nitrates are readily soluble, their rapid movement into the groundwater can be expected. High nitrate levels therefore can occur in perched groundwater, particularly during periods of high evaporation and sublimation, which tends to concentrate the solutes within the groundwater. It could be expected that the grasslands which likely rely heavily upon the perched groundwater, could be profoundly impacted. The high nitrates would offer a selective advantage to highly productive invasive species—both native and exotic-- which were previously restrained by the paucity of available nutrients. Leaching studies evaluated within the FEIS indicate bleed through of nitrogen.

In general the FEIS language related to nutrient impacts upon the ecological stability of the area is presumptive at best. It is not realistic to make reliable long-term projections of change considering the extent of departure from the successional history of the involved ecosystems.

PHOSPHORUS

The FEIS discussions related to increased phosphorus loading associated with snowmaking was limited to studies within the laboratory of leaching rates through collected soil columns. These tests provided some indication that phosphorus would be retained within the soils and would not be expected to leach into the groundwater. However, the laboratory testing must be considered limited because of the short time duration, the lack of seasonal fluctuations, and the absence of complex biological activity which would be seen in the field. The initial water sample used in the leaching tests, which presumably was the effluent used for snowmaking, was noted to contain <2.0 mg/L ortho-phosphate (also known as Soluble Reactive Phosphorus or SRP which is readily bioavailable), which is lower than the presumed 3 mg/L total phosphorus used to develop Table 1 in this text. It is unclear if organic phosphorus was considered, as this is often a common form within wastewater effluents. No other effluent phosphorus levels, including any summation of long-term phosphorus levels in the Rio de Flagg were given in the FEIS studies.

It is apparent from the FEIS text that phosphorus was not seriously considered as an influential factor in the ecological dynamics of the region. This may be because it is assumed there is an abundance of available phosphorus as the volcanic soils are comparatively high in phosphorus—about 0.10% to nearly 0.20% as phosphorus (circa 0.30%-0.55% as phosphate) on a dry weight basis. However the surficial soils are noted to be low in phosphorus, as shown in Table 3I-35 of the FEIS.

Phosphorus dynamics within soils is driven by complex interactions of factors such as adsorption-desorption, precipitation, temperature, resolubilization, diffusion, pH and Redox potential. These are influenced by climate, moisture, biological activity and the presence of organic material. While the volcanic soils associated with the study area have substantial ability to sequester phosphorus, which certainly has to a large extent influenced the ecological successional processes, it is not known with any certainty how the dynamics of phosphorus movement and biological availability will be impacted by the substantial increase in phosphorus loading.

SUGGESTIONS

Considering the inherent uncertainty of the consequences of high level nutrient loading, and other actions, upon the stability of the ecosystems associated with the study area, it would seem prudent to establish a group of qualified and diverse investigators to conduct a detailed, independent, and objective review of the proposed action (Alternative #2) which would extend beyond the presumptions included in the FEIS. Such investigation would include field work and a comprehensive literature review as well as consultation with other experts, including the indigenous peoples.

Historically, the indigenous peoples in the wide region of the San Francisco Peaks have objected to the impacts associated with the development and operation of the Resort. It is important to note that these objections based on their indigenous traditional ecological knowledge may have validity based on our initial review. The indigenous history and implementation of traditional ecological knowledge of the region would benefit any long term plans aimed at restoring the health of this ecosystem.

A final report would be joint effort by all of the mentioned contributors to include a review of the potential impacts to the associated ecology, as well as long-term economic considerations and the nature of cultural impositions. This report would include an assessment of impacts, options for reparation, and methods for assigning responsibility for correction and compensation for any damages done as a result of the implementation of the proposed action.

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