Community Vulnerability and Resilience in Disaster Risk Reduction: An Example from Phojal Nalla, Himachal Pradesh, India.

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ABSTRACT

International Disaster Risk Reduction Frameworks and Indian Plans advocate shared responsibility for reducing disaster risk, in which community vulnerability and resilience conditions are central. This paper presents a case study from the Indian Himalaya (Kullu District) of community vulnerability and resilience conditions following damaging floods, primarily the 1994 Phojal Nalla flood, through the concepts of community heritage and capital.

Data were collected in the period 2013-2016, using semi-structured interviews (*n*= 129), village reconnaissance and archival/contemporary data searches. The connections between heritage, capital, vulnerability and resilience are complex, but results demonstrate 'knowledge' is the principal driver of resilience conditions, via facets of heritage (e.g. religious infrastructure and activities, traditional architectural vernacular, and multi-generational attachments to place) and capital (e.g. income diversification, access to communication technologies, societal welfare measures and positive interactions with water). Persisting vulnerabilities stem from differential access to and implementation of best practice knowledge, governed by social, economic and political conditions. Further improvements in risk reduction require greater consideration of: (1) the integration of community local knowledge into the overall disaster management process; (2) the opportunities offered by mobile phone and other technologies for generating and sharing knowledge across society; (3) the value of under-utilised knowledge of past disaster events, assembled from a systematic evaluation of oral, documentary and landscape evidence, to risk reduction.

KEY WORDS: Heritage; Capital; Vulnerability and Resilience; Disaster Risk Reduction; Flood Hazard; Indian Himalaya.

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INTRODUCTION

Natural hazards continue to pose severe risks to vulnerable communities, especially in low- and middle-income countries, despite global reductions in numbers of disasters, numbers of people affected and costs (UNISDR 2015; Munich Re 2016). Showing a recent increase in disaster occurrence and costs (150 events a^{-1}, c. US$79 billion in 2016) (CRED 2016, 2017), Asia accounts for 70-80% of fatalities (Munich Re 2016). In the period 1996-2015, India suffered the 5th largest disaster mortality, witnessing an increase in both flood events and deaths (CRED-UNISDR 2016). The Sendai Framework 2015-2030 (UNISDR 2015) and the Indian National Disaster Management Plan (2016), aim to improve Disaster Risk Reduction (DRR) through people-centred, resilience-driven approaches at the community level. With this rationale, this paper presents a bottom-up analysis of community heritage and capital contributions to DRR.

The case study involves a multi-disciplinary evaluation of villages in the Phojal Nalla catchment (Himachal Pradesh, northwest India) that have been impacted by damaging floods and earthquakes. It describes how elements of community heritage and capital contribute to DRR (Johnson et al. 2014). The objectives are to: (1) document the current heritage and capital status, and appraise how both have influenced development of vulnerability and resilience; (2) evaluate approaches to improving resilience, particularly the emerging role of mobile phone technology, and (3) discuss how enhancement of community DRR in Himachal Pradesh aligns with policy contexts.

Following UNISDR 2017 terminology, *Vulnerability* describes conditions which 'increase the susceptibility of an individual, a community…to the impacts of hazards'; and *Resilience* is the ability of a community exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard (UNISDR 2017a). We postulate that a community's heritage exerts a significant influence upon its vulnerability and resilience. In addition, we consider *Heritage* to be a complex and evolving characteristic including tangible (objects such as buildings, monuments and artworks) and intangible (socio-cultural values and practices such as those embedded in language, oral histories, religion, etc.) entities. Intangible heritage is influenced by life experiences, thoughts and knowledge and is shaped by conditions including

impacts of hazard events and the risks of future such events (e.g. Smith 2006; Harrison 2013). Kirmayer et al. (2009) establish that *Capital* possesses some similar attributes. We define *Capital* as how society organises itself, drawing upon its institutions and resources, resulting in different patterns of human-environment interactions (Wilson 2012; Collins 2009). Capital may be expressed as economic (e.g. finances and infrastructure), social (e.g. social, political and cultural networks), and environmental (e.g. use of resources).

Together, heritage (i.e. values, practices, knowledge and objects) influences and is influenced by community economic, social and environmental capital (i.e. networks, services, structures). This intersection of heritage and capital conditions community vulnerability and resilience in the face of hazards (Gardner 2015). Resilient communities exist when both are well developed, facilitating coping and adaptive behaviours (Kirmayer et al. 2009). This broad conceptual approach guides our analysis of society and environment interactions that disaster risk reduction frameworks must better accommodate at the community level.

STUDY AREA & DISASTER EVENTS

The Kullu District

The Kullu District is a high mountain region in Himachal Pradesh, India and Phojal Nalla (*nalla* = river) is a tributary of the Beas River in the Kullu Valley (Figure 1). Altitudes range c. 1000-6600 m ASL, with landcover/use comprising glacier/rock/tundra/forest (77%), agriculture/horticulture (19%) and dense settlements on river terraces and fan complexes (4%) (Chandel et al. 2013). The summer monsoon and winter snowfall climate, alongside active seismicity are important drivers for the contemporary hydro-geomorphic systems. These have produced regional and local hazard events, including: earthquakes, floods, debris flows, slope failures, avalanches, wildfires, crop infestations and epidemics (e.g. Gardner 2002; Sah and Mazari 2007).

Significant hazard events can result in disastrous impacts when associated with vulnerable communities and assets; which in part reflect underlying heritage and capital. In the Kullu District, these conditions have developed in association with a succession of local and regional governance systems over a millennium, followed by British colonial administration (1846-1947),

and post-1947 Indian independence under Punjab and Himachal administration (Singh 1982). Present demography includes a resident population of c. 440,000, total literacy of 79% and strong religious homogeneity (95% Hindu) (Chauhan 2014). Annual transient flow of economic migrants, pilgrims and tourists (>1 million in 2004; Singh 2008) swells the population, resulting in settlement expansion (Online Resource 1) beyond traditional hazard averse locations thus elevating exposure (Gardner 2002).

FIGURE-1

Phojal Nalla catchment

The catchment (1415-5100 m ASL; 130 km^2; Online Resource 1) contains small areas of permanent snow/ice, has forest cover, and exhibits evidence of slope failure and river flooding. At its confluence with the Beas River a fan complex has been a focus of permanent and transient occupation (Anon 1884) despite past disaster impacts. The catchment has been used over many generations for subsistence agriculture, pastoralism and, more recently, horticulture. The primary villages, Phojal, Dobhi and Dawara are located at lower elevations (Figure 1 c). Alike many Beas River tributaries, recent development transitions arise from small hydro-electric power (HEP) generation plants (8 in Phojal Nalla) and transmission facilities (HIMURJA 2015; HPPTCL 2015). Implications of these schemes are unfolding, and may eventually be similar to those reported elsewhere in the Kullu District, including improved road networks, loss of cultural assets, removal of trees/horticultural land, diverted channel flows, and modified soil erosion and flood risks (Kumar & Katoch 2015; Diduck & Sinclair 2016).

Though fragmented, hydro-climate data for Phojal Nalla (Online Resource 2) indicate that pre-monsoon snowmelt and summer monsoon rainfall are important elements in the annual hydrograph. Given Jangra and Singh (2011) report the wettest months are July and August (rainfall up to160 ± 82 mm, 1σ; for the period 1962 to 2009, at Naggar Farm 7.2 km ENE of Phojal). Whilst BEHEPD (2009) indicate gauged discharge of Phojal Nalla at Dobhi Bridge (3.7 km downstream of Phojal) peaks May to August. Recent warming and an increased frequency of severe weather also may be emerging as important drivers. The existing stream flow record

(1967-1983) is too short to be representative. However, flood events/impacts have long been recognised at Dobhi/Dawara, for example, Cunningham (1848, p208) details *'Phajtrâni* [Phojal Nalla] *is a large unfordable nullah, with a bed full of boulders'*. Significant recorded flood events include: (1) summer 1894, when a landslide-dam outburst flood resulted in substantial loss of life amongst migratory traders, encamped at Dawara (e.g. The Times of India 1894; LRA 1896; Gardner 2002); (2) August 1952 and August 1957, when the NH-21 'temporary' road bridge at Dobhi was repeatedly damaged and lost (e.g. The Tribune 1952, 1957). In contrast, the April 1905 Kangra earthquake was a regional scale disaster, locally manifest by ground shaking and landslides, that caused damage to buildings, trails and irrigation channels, and resulted in the loss of life and livestock (Rennick 1905; Waterfield 1905).

While accounts detail Kullu Valley history (e.g. Harcourt 1871; Forbes 1911), specifics of in-catchment villages are scarce. Records and maps reveal small communities using regulated local resources. For example, Phojal in c. 1884 comprised 71 houses, 58 families, 165 cattle, 405 sheep, and 148 goats (Anderson 1884). Land was irrigated, with 130 ha under cultivation in 1891 (Coldstream 1913). Phojal Kalaun forest (32 ha) had 'protected' status with controlled rights of use and access (e.g. Anderson 1884). The most recent Kullu District Census Handbook (Census of India 2011a) reveals Phojal village (75 ha) has a growing population (492 persons) and an increasing number of households (102). Listed village amenities include: education (primary and middle schools), medical facilities via a traditional practitioner and a pharmacy, treated tap water but an absence of formal/ treated drainage, sub post office, telephone connectivity (landline and mobile) but no internet café service, public and private bus services, major/other district and gravel road statuses, and an electricity supply. Furthermore, in Phojal, 62% of persons are classified as literate, and in the main working population 93% work as 'cultivators' (Census of India 2011b).

DRR questions are assessed relative to past disasters, particularly the 9-10 August 1994 flood of the Jawala Mukhi Nalla in Phojal (Figure 1, Online Resource 3). Whilst more recent floods have occurred in the wider Beas River basin, the 1994 event remains the most recent/ significant to impact the study tributary and villages, consequently it is well embedded within

oral, documentary and geomorphic evidence sets. We suggest that the 1994 legacy contributes to the local resilience, as some in the community are able to draw upon their individual experiences and collective memories of the 1994 flood. In synopsis the 1994 event characteristics and impacts included: heavy convective rainfall, slope failures in pastures coupling with channels resulting in sediment/woody-debris transfer and deposition, channel enlargement, destruction of horticultural land, loss of harvested apples, and human/livestock fatalities.

METHODS

The Phojal Nalla catchment was selected following a review of regional literature, Google Earth imagery and preliminary field reconnaissance (April 2012). These demonstrated opportunities for research on emerging DRR questions, given: (1) geomorphic evidence of past hazard events; (2) a transitional setting where traditional life co-exists alongside development-led changes, in a region that elsewhere has undergone rapid change; (3) availability of documentary accounts owing to close proximity to trade routes, and colonial era fruit orchards and governance hubs. Our methods include: (1) semi-structured interviews; (2) village reconnaissance; (3) archival and contemporary data searches and analyses.

Semi-structured interviews

Interviews were conducted with the assistance of Hindi-English interpreters, so in most cases responses best reflect the sentiments rather than the verbatim voices of interviewees, all of whom provided informed consent. Respondents (male and female) were sampled by appointment (i.e. persons with societal responsibility, identified via research/local recommendation) and also opportunistically amongst the wider community; as generalised in Tables 1-3. The interviews (*n*= 129, ranging c. 10- 120 minutes) were recorded with video and contemporaneous handwritten notes, and were undertaken within catchment villages (Figure 1) and also more distant locations (i.e. Kullu, Patlikuhal, Shimla), during the period April 2013 to April 2016.

Interview schedules provided core themes (related to hazards, village life, and development) to enhance consistency of data collection across interviewees. Reflection resulted in additional questions and follow-up interviews with some existing interviewees. Transcribed narratives were coded (manually) via core themes. These are assessed according to indicators of heritage and capital and provide some corroboration of conditions.

Village reconnaissance

Observational walks around villages and their surrounds, frequently with the assistance of locals and following routes according to their priorities, enabled the identification of tangible heritage indicators, vulnerabilities and resilience assets. Data were recorded using photographs, notes, map annotation and GPS waypoints.

Archival and contemporary data

New compilations of documentary knowledge from Indian, UK and USA sources were derived from materials held by archives, libraries, universities, research institutes, learned societies, private collections and government departments. Materials include published texts, colonial era reports and diaries, newspapers, research theses, historical maps/photographs/drawings/ paintings, gazetteers, meteorological data, and DRR and HEP planning documents. In all cases access, search and copy procedures were pre-established with collection key holders. The search criteria were a consistent array of geographical and topic keywords, and included pre-visit review of catalogues where available.

HERITAGE, CAPITAL, VULNERABILITY & RESILIENCE CONNECTIONS

Original syntheses of the heritage and capital statuses are presented in Tables 1-3. These are structured according to village, heritage type (tangible *[T],* or intangible *[I]*), capital type (economic *[E]*, social *[S]*, or environmental *[En]*), and indicator type (*T1-5; I1-4; E1-6; S1-5; En1-3*). Table 1 deals with heritage and Tables 2 and 3 with capital. These provide a broad overview of contemporary conditions, enabling a starting point in the exploration of life in these mountain villages. They reveal community diversity and complex interconnections across the conceptual

base, which condition responses to disaster risk; here, rather than being comprehensive, we have focused on those conditions with the most evident linkages to vulnerability and resilience.

TABLE-1-2-3

Appraising village heritage and vulnerability/resilience relationships

Table 1 reveals traditional ways of life are intertwined with modern inclusions that shape the evolution of heritage. These are reflected in expressions of: religion; architecture; local knowledge; multi-generational family attachments to place, property and business; craft, fabric and garment production; and the roles of song, dance and music. Here we further discuss the first four.

Religion is central to village identity, particularly in the Kullu District where village deities are celebrated. Our data reveal Hinduism dominates, alongside a Tibetan Buddhist community in Dobhi (Table 3 *S2*); however no details of religious denominations were obtained. Religious heritage is evident in infrastructure, beliefs, and activities (Table 1 *T1, I1;* Berti 2009). For example, temples and funeral pyres exist in the villages (Figure 2 a). Prayer and belief in divinities span life activities (e.g. marriage, fertility, agricultural productivity and times of ill health), as do religious festivals/fairs such as the Phojal Kapu Mela and the Kullu Dussehra. These religious assets and activities (Table 1 *T1 & I1*) are important in resilience generation. Temples are highly valued structures and village gathering points (Handa 2015) that could reflect knowledge of low-exposure locations, around which other buildings congregate. For example, in Phojal both temples are located well above Jawala Mukhi Nalla (Online Resource 1). Further, temples are constructed of wood and stone, reflecting traditional building materials and typologies that possibly provide superior seismic resistance (see later). Religious activities, such as the annual Phojal Kapu Mela, enable large gatherings to trade resources, exchange knowledge (including by song, dance, and music; Table 1 *I2*) and foster social connectivity (Minhas 1998), all of which provide opportunities for enhancing resilience. In contrast, the traditional *fait accompli* belief that hazard impacts are in the *'hands of god'* (*Da7*; Tables 2 & 3 *En3*) does weaken resilience (HPSDMA 2016). It is however important to recognise that this

fatalistic (high-vulnerability) standpoint is not universal amongst the local community; given evidence (Tables 2 & 3 *En3*) clearly reveals a more active approach to living with hazard and risk. Consequently our interpretation of religious belief systems and connections with DRR in this region requires nuance and warrants further investigation.

The local architectural vernacular (Figure 2 d) is typified by small gabled buildings of wood, stone and slate where living quarters are above ground-floor cattle sheds (e.g. Handa 2015). This style is more common in Phojal/Runga (Table 1 *T4*) and less so down valley, where reinforced concrete and brick buildings now dominate (Tables 2 & 3 *E4*). This may reflect differential road access (Figure 1), the growing supply of cement and steel, and a reduced/regulated timber supply (Pawar and Sharma 2012). Interviewee *N1*, notes that modern buildings are also increasing up-valley as *'…people are following each other...it is becoming a status symbol, if you are having houses which are built with the help of brick and cement, it is good'*. Construction using traditional approaches is arguably an expression of heritage informed resilience, as it demonstrates how local resources and craft skills seek adaptation to the geophysical (reinforced structures) and climatic environment (steep roofs in areas of heavy snowfall); although bringing greater vulnerability to fire. However, the growing use of modern building materials may alter the vulnerability and resilience conditions as different structures and materials respond differently to seismic shocks. Accounts from the Kullu Valley following the 1905 earthquake indicate that traditional timber-bonded buildings outperformed masonry-only buildings (O'Brien 1905); a view that remains today, for example: *'if it is a heavy earthquake, the old houses around the village are much stronger and safer than concrete/brick houses'* (*D3*). Nonetheless, technical assessments demonstrate that seismic vulnerability is more complex, reflecting materials, structures, geometry, conformity with building codes and maintenance (Arya 1992; IIT 2013) as well as specific locational attributes such as slope and soils.

Local knowledge is both a tangible (Table 1 *T3*) and intangible (Table 1 *I4*) heritage, that exists within and beyond the catchment. Focussing on past disasters (e.g. 1894 and 1994 floods, 1905 earthquake), first-hand accounts of event impacts and coping strategies are revealed by archive documents (Table 1 *T3*) including Phojal's record book (Figure 2 c), landuse maps of

Phojal (Figure 3 d), and villager's oral histories (Table 1 *I4;* Tables 2 & 3 *En3*). A key finding is that knowledge of disasters is more detailed and widespread in up-catchment villages amongst the indigenous population, where some of those directly impacted in 1994 still reside. This knowledge has resulted in adaptations to reduce exposure to future flood damage (Gardner and Dekens 2007), such as limited rebuilding alongside the Jawala Mukhi Nalla in Phojal. However, a recent, albeit single exception exists, with the construction of a new building in a location severely impacted by the 1994 flood (*P1*, Figure 3 d). This example poses questions about: the retained potency of past disaster knowledge; accessibility of officially kept knowledge (e.g. village records and archive materials); the efficacy of formal education programmes (i.e. paucity of DRR in the school syllabus, Table 2 *En 3*); and the suitability and implementation (regulation and deterrence) of land use policy (Rautela 2016). The connection between knowledge and vulnerability and resilience is therefore complex.

Multi-generational family groupings with attachments to place, property and business are common themes in all villages (Table 1 *I3, I4*). For example, indigenous interviewees recall: *'he has been living here since birth and even his forefathers lived here…his house was built by his grandfather and father'* (*P17*); *'the family have owned the shop since 1968, and he succeeds his grandfather'* (*Da 8*). The implications of this attachment, crosses all three previous areas of discussion, as the family group is one societal structure that enables inter-generational sharing of knowledge and maintenance/evolution of ways of life within communities, that have been shown to influence vulnerability and resilience conditions (e.g. Dekens 2007).

FIGURE-2

Appraising village capital and vulnerability/resilience relationships

Tables 2 & 3 outline capitals within catchment villages. Drawing from this breadth, as in the previous section, we focus on conditions with evident linkages with vulnerability and resilience, namely: economic (income/finance; technology), social (indigenous versus migrant communities) and environmental (interactions with water).

Economic

Income is likely to be more vulnerable when dominated by single sources, e.g. the prevalence of specific forms of agriculture and horticulture in Runga and Phojal (Table 2 *E1*). Here crop yields are subject to meteorological variability (Basannagari and Kala 2013) as well as diseases and infestations. For example, a farmer in Runga states: *'we experienced a change in the weather/climate; the amount of rainfall and snowfall are now reduced, causing problems for crop production, particularly when it is warm* (*R4*). They do however employ coping mechanisms: *'if there is sustained rainfall or drought we use harvested products frugally so they last longer'* (*R4*). Income from crops is also contingent on market access that can be disrupted on roads exposed to natural hazards (Sah and Mazari 1998; Berkes et al. 2000). Indeed, during the 1994 flood, road access was disrupted during the apple harvest season; Phojal's Village Head (*P5*) indicated 100-150 metres of roads were lost, preventing vehicular passage for 12-16 months. Community and individual vulnerability may be reduced when income is received from multiple sources, e.g. business (services and craft products such as fabrics, woollen garments and baskets), tourist trade and government employment activities (Table 1 *T2* & *T5*; Tables 2 & 3 *E1*; Figure 2 b). However it is too simplistic to assume income diversity translates into greater net income or financial reserves for all, without undertaking more detailed budget analyses. Access to credit sources, cash (Tables 2 & 3 *E3*) and bank accounts for women (Table 2 *E2*; Girard 2014) all reduce vulnerability and enhance resilience, by empowering life activities (e.g. Collins 2009). However, in contrast, credit is not available to the Nepalese segment of the population (Table 2 *E3*).

Technological advances (Tables 2 & 3 *E5, E6, En2*; Tiwari 2010) also enhance resilience via improved communication (e.g. mobile phones and satellite TV), mobility (e.g. private/public transport and road network expansion) and supply of mains electricity. Focussing on TV and mobile phones, ownership seems prevalent in the study villages with a few exceptions amongst some elders, who therefore retain some vulnerability as they are not afforded the same depth and immediacy of communication. Of those with TV's, many have watched documentaries and local news bulletins about hazard events, thereby developing their knowledge and enhancing their capacity for resilience. For example, in relation to floods: '*The district administration*

informs people on TV…they order people to empty their home and go to safe areas' (*Do8*); *'this area is a vulnerable area for disasters…heard it from the news'* (*P18*). In the case of mobile phones, the IT shopkeeper in Phojal (*P19*) suggests that he has sold many devices, witnessing high-levels of ownership in the last 10-15 years. Herein younger generations have good devices; he himself uses WhatsApp messaging software, and with this has seen pictures of Beas River floods rather than being informed by word of mouth. Despite this uptake, in parallel, there is limited computing hardware availability, low Internet usage, and no local formal education using online tools (Table 2 *E5*). For example, in Phojal and Runga only 30% use the Internet (*n*= 16; 2015-2016) (Table 2 *E5*). In contrast, c. 60% of the Dobhi Tibetan community are users (Table 3 *E5*). *P19* indicates many of the mobile phones he has sold have Internet capability, but whether people use this is another question. He also suggests few people in Phojal, perhaps *'2, 3 or 4'* have a personal computer.

S*ocial*

Previous discussions about heritage have shown that religious assets/activities and indigenous family networks provide a means of social interaction and knowledge transfer; offering a capacity for resilience generation. However, in exploring social capital, further dimensions are revealed, in particular the experiences both between and within indigenous and migrant communities. The character of this resident local population is complex, with seasonal migrants from nearby Lahaul-Spiti District, Tibetan exiles, Nepalese economic migrants, women moving villages for marriage, along with those returning from higher education or distant careers such as military service (Table 1 *I3;* Table 3 *S2*).

Resilience stems from societal measures that assist wellbeing and livelihood, as these broadly enable people to be healthier, more informed and mobile in the face of disaster risk. Herein, indigenous and migrant communities may share the benefits of democratic governance (Table 2 *S3*), health awareness programmes (Table 2 S4), free elementary education (Table 2 *S5*), and tolerance of different religions (Table 3 *S2*). Indigenous populations further benefit from women's gatherings and farmers' discussions on crop husbandry to manage adverse weather impacts (Table 2 *S2*). The Tibetan migrant community in Dobhi has also implemented a social

programme to develop self-sufficiency (Table 3 *S2;* CTA 2014). A Tibetan Official (*Do9*) details the welfare facilities: formal and free housing for families, access to schools, a community hall, and freedom to work in the local economy rather than being forced to produce handicrafts.

Societal divisions do remain, conditioning access to knowledge and life services, resulting in greater vulnerability of some. Observations reveal weaknesses across all communities relating to: caste and gender (low caste and females disadvantaged; Table 2 *S1;* Sharma 2013); alleged corruption in association with HEP developments (Table 2 *S3*); deference by some to official organisations for hazard management instead of developing self-sufficiency (Table 2 *S3*); and absenteeism from school, with Nepalese families often favouring income generation from child labour (Table 3 *S5*). More explicit is the segregation of settlement locations, with migrant communities living in higher flood risk locations, e.g. Nepalese alongside Phojal Nalla (Table 3 *E4, S2;* Online Resource 1 b) and Tibetans on the Dobhi fan adjacent to the Beas River (Table 3 *S2*).

Environmental

Variations in vulnerability and resilience across communities can be explored further by evaluating their interactions with water quantity (i.e. floods) and quality.

In the case of the Tibetan community, whilst typically lacking multi-generational attachments to place that facilitate deeper local knowledge, they do have some awareness of past flood events and prevailing risk, but their ability to minimise flood exposure is constrained. For example, *Do9* indicates the Tibetan community are aware of the Beas River flood risk and have improved resilience by building flood defences. In respect to establishing the community in this location, he suggests they live with a vulnerability legacy: *'our first generation people…they didn't have alternative options…they had money problems, this river bed area is very cheap'.* Flood resiliency is also apparent in the indigenous Phojal/Runga community. Following the 1994 flood coping and adaptive strategies were employed (Table 2 *En 3;* Figure 3), specifically response (i.e. evacuation and search), recovery (i.e. clean up, sharing of resources, and financial loss adjustment) and coping mechanisms. Longer term adaptations to bolster future resilience

included tree planting, river engineering, education posters, emergency action signs, and landuse/ownership mapping. In contrast, as revealed previously, floods are not commonly perceived as a problem by indigenous residents down catchment in Dawara and Dobhi (Table 3 *En3*), despite the historical record (see accounts herein) and future hazard potential (Gardner 2002). For example *Do8*, who resides on the fan complex (0.2 km from Phojal Nalla) states, '*we don't have any problem about the flood as we are very far away from that flood, so we are protected and safe here'.*

In terms of water quality, Phojal has measures to improve wellbeing (vulnerability reducing), with a separation of water supply and public sanitation functions (Table 2 *En1*). In contrast, Nepalese migrants in Bulang and Dawara were observed using the river for washing and excretion, reducing the water quality (Table 3 *En1)* which decreases wellbeing (vulnerability increasing).

FIGURE-3

APPROACHES TO IMPROVING FUTURE RESILIENCE

The foregoing appraisals reveal several key findings:

(1) The importance of religion for societal connectivity and knowledge transfer in villages, for example in respect to building locations to avoid floods and traditional architectural styles using mixed building materials to enhance resistance to earthquakes.
(2) The significance of multi-generational family units in life activities; providing a mechanism for the retention, sharing and evolution of knowledge. This is apparent in awareness of past local disasters and how communities use coping and adaptive practices to reduce future disaster risk and manage the impacts of weather variability upon crops.
(3) The existence of complex disparities in the implementation of best practice knowledge. In particular, variations in vulnerability and resilience to disaster risk are observed

according to: age, caste, religious beliefs (i.e. fatalism), gender, location, migrant or indigenous origin, and political/economic standing in society.

These findings confirm the importance of societal networks, socio-economic-environmental conditions and the use of knowledge as pathways to improved community resilience (Gardner and Dekens 2007). An emerging opportunity for improving resilience is afforded by mobile phone technologies. Our findings reveal wide scale uptake of hardware in villages, but in parallel we found gaps in ICT education and limited use of internet services. Existing research considers mobile phones increasingly important for risk awareness and resilience generation in developing nations (Ospina and Heeks 2016), given the technology's capabilities for: rapid and equitable delivery of information and warnings; real-time flows of information between disaster managers and the public; and generating social media peer networks resulting in enhanced self-organisation and shared responsibility prior to, during, and after disasters (e.g. Dufty 2012; Alexander 2014; Vos and Sullivan 2014). Mobile phones also provide a means to share local knowledge more broadly, thus counteracting some of the disparities identified in this research. This advocacy for digital empowerment of society aligns with Indian Government policy (Digital India 2017). Herein, a set of practical implementation measures are required to achieve improved resilience, but to be effective these need to be founded on a better understanding of Indian telephony adoption (Gupta and Jain 2015), and navigate the complexities of top-down versus locally-integrated pathways to resilience.

This wider debate about how best to govern improvements in resilience is important, given exposure and vulnerability to hazards are increasing in mountains despite existing DRR initiatives (Hewitt and Mehta 2012; Gardner 2015). This questions the effectiveness of western-dominated DRR approaches, i.e. hazard focussed (impact prevention and event response), based on formal knowledge, governed within technocratic contexts by top-down power structures (e.g. Dekens 2007; Gaillard 2007; Mercer et al. 2009; Hill 2013; Kaul and Thornton 2014). Consequently there has been a call for localised, participatory and pre-disaster development-led approaches to be mainstreamed in DRR, to better reduce vulnerability and increase resilience (e.g. Kaul and Thornton 2014; Le Masson 2015). Central here are 'local

knowledge systems', which Dekens (2007) and Mercer et al. (2009) conceptualise as locally existing and transferred, place-based knowledge types, practices, values and beliefs; all synonymous with the conceptual base adopted in this paper, especially heritage. Key tenets are: (1) the importance of local knowledge in identifying problems, priorities and solutions proportionate to local resources; (2) community empowerment using culturally compatible tools to encourage trust, understanding and a depth of ownership to sustain actions; (3) a focus on the vulnerability resilience nexus. These tenets share aspirations with polycentric governance models (e.g. Ostrom 1999; Feldman 2014) and adaptive co-management principles (Armitage et al. 2009). The former involve nested, independent, and parallel governance units to provide redundancy to better deal with complex system dynamics. Such a structure, while often encompassing technocratic and scientific solutions, also empowers local contributions, via self-organised unofficial entities and/or elected bodies (for example Indian village panchayats). The latter supports a long-term institution-building process within and between communities and government agencies (i.e. bonding, bridging and linkage relations); in which participants share and use a plurality of knowledge to best adapt to complex society-environment dilemmas. Consistent with this, in the context of DRR, many advocate the value of combining western scientific (hazard) and local knowledge and methods (e.g. Chen et al. 2006; Mercer et al. 2009; Hiwasaki et al. 2014), to provide a synergy of capabilities. Such an approach, involving shared responsibility negates an over emphasis on locally-led resilience, which Frerks (2015) notes could otherwise serve an agenda of excusing the state from responsibility to protect the interests of vulnerable citizens.

IMPLEMENTATION OF DRR POLICY AND PLANS IN INDIA

International policy frameworks provide high-level guidance and collective priorities for DRR; foremost is the 'Sendai Framework for Disaster Risk Reduction 2015-2030' (UNISDR 2015), of which India is a signatory. Additional international policy groups, in the case of India, include the BRICS task force on disaster risk management (UNISDR 2016b) and the AMCDRR (Asian Ministerial Conference on Disaster Risk Reduction). In November 2016, the latter adopted the 'Asia Regional Plan', reaffirming the principles of the Sendai Framework and providing a co-operative pathway to implementation (UNISDR 2016c). Zimmermann and Keiler (2015) suggest

the Sendai Framework is a step forward, as it advocates a stronger focus on the underlying causes of vulnerability and risk; a need for shared responsibility for action across society; and the development of implementation tools. In particular, the Sendai Framework (24 (i)) advocates the use of both local and scientific knowledge in DRR, with implementation tailored to the local context. Academic and policy initiatives therefore share common directions; however the effectiveness of any international policy rests in its national/sub-national implementation.

Indian implementation of the Sendai Framework includes the Indian National Disaster Management Plan (2016), which follows the 2005 Disaster Management Act (NDMA 2005); this devolves responsibilities primarily to State and District governments (Rautela 2016). Himachal Pradesh continues to transition to the Sendai Framework, with revision of State and District disaster management plans (HPSDMA 2017). Herein, the most recent (June 2017) Kullu District Disaster Management Plan (DDMA 2017) promotes a stronger alignment with the Sendai Framework, in that it seeks to integrate DRR into government-led development projects to build a 'self-resilient society', in which 'bottom-up' approaches are championed. Accordingly, emphasis has been placed on generating greater community involvement, alongside other stakeholders, by mandating new 'Village Disaster Management Committees' with responsibilities for *'awareness generation; warning dissemination; community preparedness plans; adopting safe housing practices; organising and cooperating relief…'* (DDMA 2017, p47). However, within this plan local communities are typically portrayed as recipients of guidance, training and equipment; rather than fully empowered to shape District policy. In addition, whilst the value of documenting and promoting 'indigenous technical knowledge' is stated, there is no clarity on the mechanisms, timescales and beneficiaries of such. Although a commitment to annual revision of the District Disaster Management Plan provides opportunity for development; this may capitalise from wider project activity in Himachal Pradesh. A good example is the Government of India- UN Development Programme project *'Enhancing Institutional and Community Resilience to Disaster and Climate Change, 2013-2017'*, offered in partnership with State and District governments. The project includes selected villages in the Kullu District, and has sought to: document indigenous best practices for DRR; identify community resilience indicators; and pilot approaches to enhance resilience to flood risk (HPSDMA 2016, 2017). This

deeper interaction with local communities, better aligns with the Sendai Framework, as reaffirmed by the UNISDR 2017 Global Platform, which drew attention to the importance of: (1) *'systematic opportunities to engage the general community… in DRR programming, design, resourcing and decision-making'* (Working Session 9; UNISDR 2017b, p55); (2) '*protecting non-tangible heritage such as cultural diversity and traditional practice and knowledge'*; *'increased integration of traditional knowledge…*' (Working Session 13; UNISDR 2017b, p59).

Furthermore, this study, points to a wealth of under-utilised local, archive and bio- geomorphic (i.e. landscape evidence of event impacts, *cf.* Ballesteros Cánovas et al. 2016) knowledge on past disasters. Indeed the Himachal Pradesh State Disaster Management Authority (HPSDMA 2017) acknowledges the existing HP State hazard-vulnerability-risk analysis atlas and report for the State is 'incomplete' and 'incomprehensive'.

The preceding analyses demonstrate growing steps towards resilience, but with scope to better integrate communities and a diversity of knowledge types into the disaster management process; echoing analyses in Lahaul (Kaul and Thornton 2014) and Ladakh (Le Masson 2015). This observation is one of a delivery gap between DRR frameworks and on the ground actions (Oxley 2013; Zimmermann and Keiler 2015). This is the thrust of the UNISDR Sendai Framework 'Words Into Action' Programme (UNISDR 2016a), which seeks '*practical guidance to support implementation, ensure engagement and ownership of action by all stakeholders, and strengthen accountability in disaster risk reduction'*. In this regard, the Government of Himachal Pradesh have appointed UNDP specialists (2015-2020) to enhance resilience, via the review/preparation of disaster management plans; formulation of training and awareness programmes; and development of measures to enhance village level resilience (HPSDMA 2017).

CONCLUSION

Disaster risk reduction is a fundamental global challenge and important to sustainable development. In mountain regions, at the community level, this is pressing, owing to rapid societal and environmental changes that have generally increased exposure/vulnerability to

hazards. In this context, DRR must include building resilience in vulnerable communities. This case study, using the concepts of heritage and capital, demonstrates the importance of understanding local relationships in undertaking DRR; where 'knowledge' is the driver of vulnerability and resilience conditions. In terms of heritage, religious infrastructure and activities, traditional architectural vernacular, and multi-generational attachments to place are important in the sharing of local knowledge in both tangible and intangible forms. In respect to capital, income diversification, access to communication technologies (TV and mobile phones), societal welfare measures/networks and positive interactions with issues of water quantity and quality reduce vulnerability and build resilience. Persisting vulnerabilities stem from differential abilities to access and implement best practice knowledge, reflecting: age, caste, gender, location, migrant or indigenous origin, political/economic standing and religious beliefs.

These findings and complexities identify avenues for local DRR and areas of further enquiry. Key to improving community resilience is an ability to decipher what knowledge exists or is needed, and how it can be best implemented. Accordingly we offer three reflections in response:

(1) While transitions to the Sendai Framework are progressing in the Kullu District, it is equally evident that community involvement and local knowledge are yet to be optimised in the disaster management process. This cross-scale gap calls for further development of a governance culture that can more effectively facilitate community collaboration alongside existing stakeholder expertise. Adaptive co-management principles, for example, offer one such governance culture and structure.
(2) The substantial uptake of mobile phones in mountain villages is a significant opportunity. Understanding the potential these and related technologies have for generating and sharing scientific and local knowledge is an emerging area of interest that can deliver new contributions to resilience.
(3) Examination of oral, documentary and bio-geomorphic evidence in this research has highlighted that much remains to be discovered and openly shared in these mountain communities, including re-connecting local populations and disaster managers with their

histories. New research that systematically builds databases of past disasters using local knowledge and scientific tools aligns with the Asia Regional Plan, which aims to establish methodologies to collect disaster loss data and risk profiles by 2020 (UNISDR 2016c).

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COMPLIANCE WITH ETHICAL STANDARDS

Participant informed consents were obtained in full compliance with institutional research ethics procedures.

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FIGURE, TABLE & ONLINE RESOURCE CAPTIONS

Fig. 1 Location of the Phojal Nalla catchment in the Kullu Valley. (a) India and South Asia; (b) Himachal Pradesh State and neighbouring areas; (c) Phojal Nalla catchment

Fig. 2 Tangible heritage assets, examples in Phojal village: (a) Temple [Higher caste]; (b) Hand loom; (c) Phojal village daily record book, outlining the flood event of 10 August 1994; (d) Variant of a traditional Kullu wood-stone composite wall, slate roofed building

Fig. 3 Resilience measures, examples in Phojal village: (a) Public education sign; (b) Important telephone numbers at the middle school; (c) Emergency route sign at the middle school; (d) Landuse ownership mapping [Original is 1:1000 cloth map. Source: Local Revenue Office, 2013]

Table 1 2013-2016 heritage status in the Lower Phojal Nalla catchment villages

Table 2 2013-2016 capital status in Runga & Phojal villages

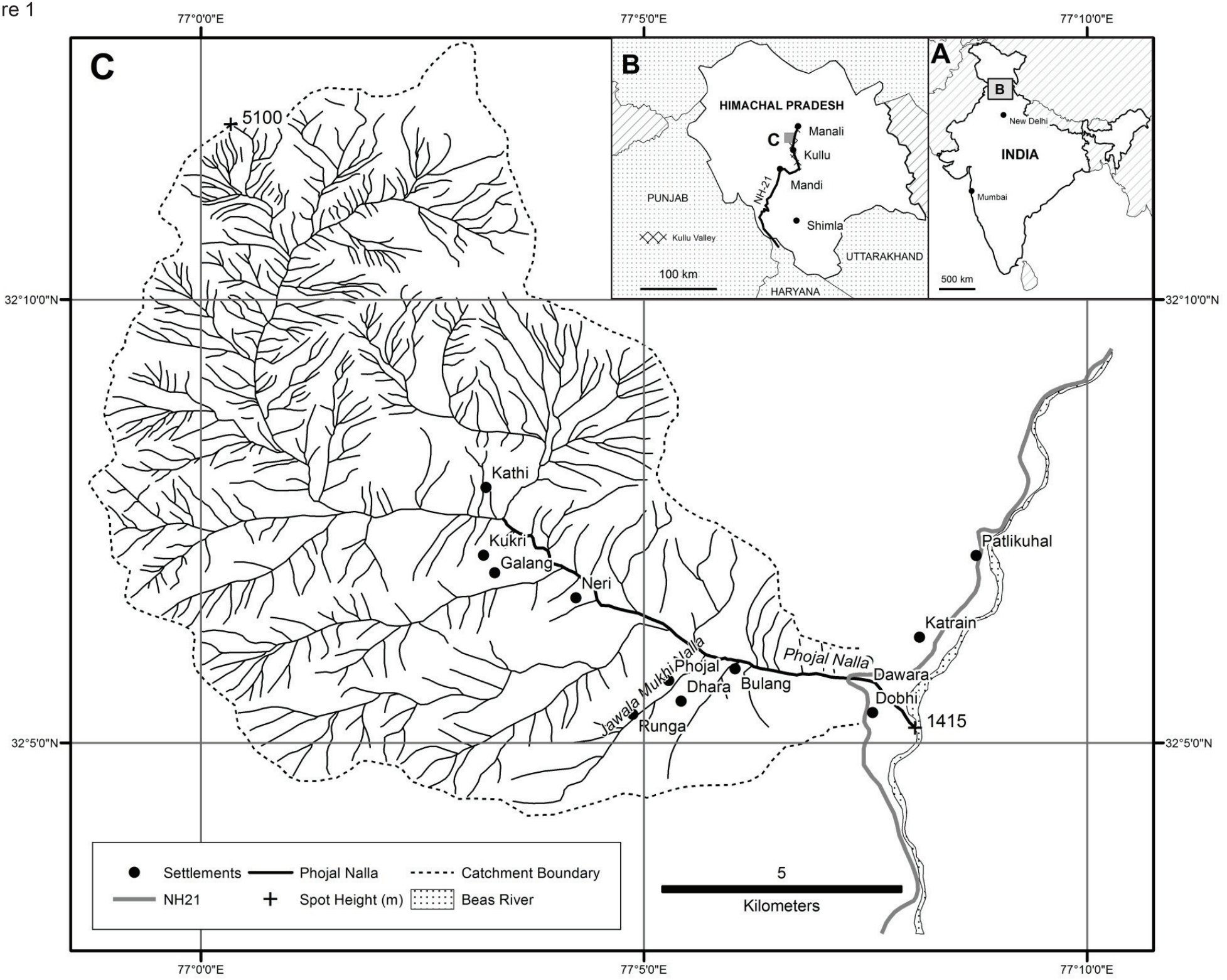
Table 3 2013-2016 capital status in Bulang, Dawara & Dobhi villages

Online Resource 1 The Phojal Nalla catchment and fan complex, as seen from near Jana [November 2016]. Inset: (a) Phojal- indigenous village footprint, inclusive of temples, on a forested hillslope above Jawala Mukhi Nalla [18 October 2013]; (b) Informal Nepalese dwellings immediately alongside Phojal Nalla at Dawara [15 April 2015].

Online Resource 2 Hydro-climatic conditions. (a) Climate at Naggar Farm [Jangra and Singh 2011]; (b) Flow at Dobhi Bridge [BEHEPD 2009]

Online Resource 3 Synopsis of the August 1994 event characteristics and natural/ community physical impacts

Figure 1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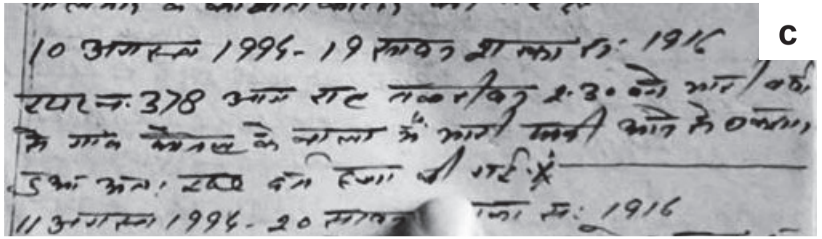
Manali
C
Kullu
Mandi
NH-21
PUNJAB
Shimla
Kullu Valley
UTTARAKHAND
100 km
HARYANA
A
B
New Delhi
INDIA
Mumbai
500 km
Kathi
Kukri
Galang
Neri
Patlikuhal
Katrain
Jawala Mukhi Jalla
Phojal
Dhara
Bulang
Phojal Nalla
Dawara
Dobhi
1415
Runga
Settlements
Phojal Nalla
Catchment Boundary
NH21
Spot Height (m)
Beas River
5
Kilometers

Figure 2

a

b

c

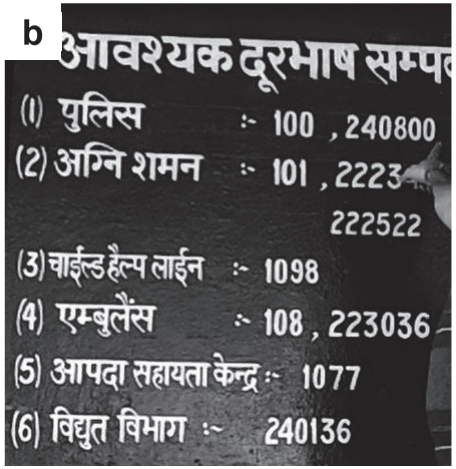


English Translation:

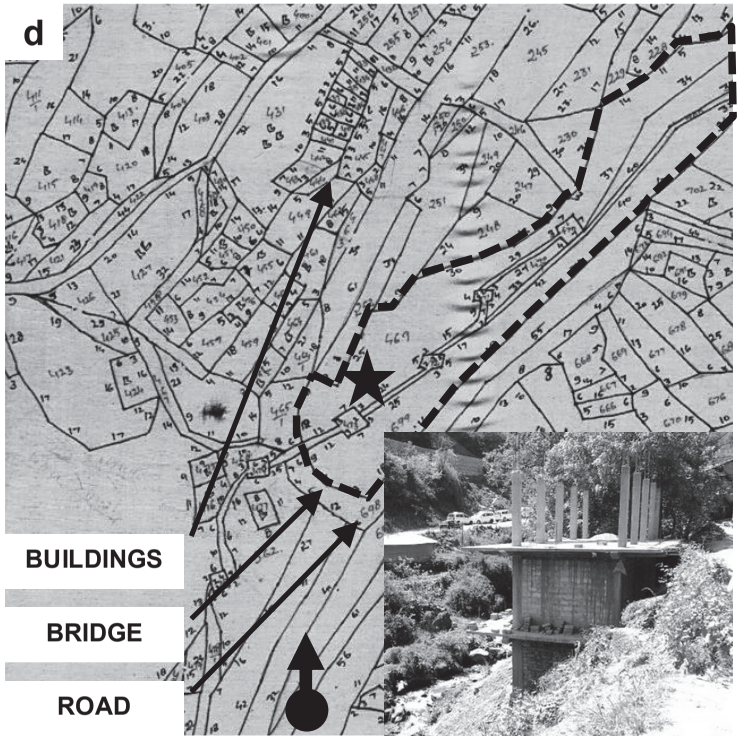
'10 August 1994, this is another date [Hindu calendar system date: 1916]… *Whole night around 2.30 AM there was a heavy rainfall and it was in village Phojal and there are few other villages which are far away from here, and later there was a lot of damage...'*

d

Figure 3



English Translation: (1) Police;
(2) Fire Brigade; (3) Child Help Line;
(4) Ambulance; (5) Natural Hazards;
(6) Electricity Department



Jawala Mukhi Nalla channel corridor at Phojal village downstream of road bridge (southerly tributary of Phojal Nalla)

Online Resource 1 a: Phojal village view point

Location of new construction (April 2016) in a channel marginal location heavily impacted by the 1994 flood (inset)

Table 1

Heritage Type	Heritage Indicators	Runga & Phojal	Bulang, Dawara & Dobhi
Tangible	**Religious Assets** *T1*	- Two Hindu Temples with wood carvings (Higher & Lower caste) in Phojal **(O, Figure 2 a)** & one temple in Runga for all people **(R2)** - Hindu funeral pyre in Phojal **(P5)**	- Tibetan Buddhist Temple on the Dobhi Fan **(O, Do9)** & additional temples in Dawara & Dobhi **(A)** - Hindu funeral pyre in Dawara **(O)**
	Crafts *T2*	- Handloom weaving of fabric from locally dyed and spun wool **(O, P6, R2, Figure 2 b)** & basket making	- Rag rug production **(Do8)** - Tibetan crafts have declined, as market concern about child labour **(Do9)**
	Village/ State Records *T3*	- Daily written accounts of local activity & events in Phojal Revenue Office **(O, Figure 2 c)** - Land settlement census data (1884-1886) and forestry rights **(A)**	- Maps held in the Dobhi Revenue Office **(O, Figure 3 d)** - Accounts of historical floods, 1905 Kangra earthquake impacts on the catchment/ surrounds, and the colonial apple industry **(A)**
	Traditional Architecture *T4*	- Local wood, stone & slate materials **[O, P18, Figure 2 d]**	-
	Traditional Dress *T5*	- Purchase clothes from Phojal/ Kullu, especially during festivals **(R2)**	- Lahaul dress- own made socks, gloves & scarfs in winter **(Do3)** - Kullu valley cap- common in cold weather **(Do1)** - Purchase clothes from other communities and markets **(Do8)**
Intangible	**Religious Beliefs/ Activity** *I1*	- Deep belief in the Gods: Phojal's statue (*Jawala*- goddess of light & fire) whilst only 20 kg can only physically be lifted by believers; pray at the temple for marriage blessings, fertility & at times of crisis; religion is taught by the family **(P1)**. Is also a male god (*Veernat*) in Phojal **(P16)** - Phojal festival *(Kapu Mela),* mid-June for 2 days, 2000 people from 9 nearby villages stay/ eat/ sing/ dance in Phojal; bringing their goddess statues to Phojal Temple **(P1, R2)** - Praying to god to protect land in the wet season, is common **(P5)**; pray for rain/ snow when drought **(R2)**	- Diversity of religions, particularly Hindu **(Da5, Da7,Do1, Do6, Do7, Do8)**; Buddhist **(Do3, Do4)** - Significant event for the entire Kullu valley is the Hindu Kullu *Dussehra*- International Festival each autumn **(O)**
	Local Dance/ Song/ Music *I2*	- State dance is *Nati*, involving 10 male, 10 female dancers & instrument players. In high demand at festivals & during village ceremonies **(O, P1)** - Song is frequent amongst female groups, relating to asking for help in times of illness & lullaby with a baby **(O, P6)**	-
	Family Networks/ Belonging *I3*	- Families have strong interconnections within/ across neighbouring mountain villages & across multiple generations **(P2, P3, P6, P14, P15, P17, P18, P19, R2, R4, R5, R7)** & out migration **(P1, R5)** - Moved to the area for marriage **(P14, R6)** - Loss of migrant communities in Phojal due to 1994 event fatalities and post-event trauma **(D3, Do8, P2)**	- Indigenous population with multi-generational connections to villages, land, businesses & individual properties **(B3, Da1, Da5, Da8, Do1, Do2, Do8)** - Moved to the area for marriage **(Da7)** - Tibetan community (c. 1000) in Kullu-Manali area for asylum; distant relatives visit in summer for moderate temperatures **(Do9)** - Cyclic annual migration between Lahul (Summer) & Kullu (Winter) **(Do3)**
	Knowledge of Village History, Changing Practices & Development *I4*	- Stories of past floods are passed between generations **(P18)**, in particular the 1894 event **(P5),** including by song **(R2)**. - Matriarch reflections **(P3)**: When she was a young girl Phojal village had fewer houses, with lots of construction in last c. 50 years; fewer people now collect fodder for cows; fewer people speak the local language - Changing diet; no longer just self-sourced but purchased **(P6)** - Changing production of wheat: no longer locally grown, instead purchase wheat **(R2, P6)**. Active flour mills remain in Phojal **(O)** - Changing services: introduction of roads; electricity; schools; TV **(P15)** - Wide awareness of/ involvement in the HEP re: consultation; compensation; legal proceedings; concern of impacts upon flora/ fauna, spring flows used for agriculture & loss of sacred Hindu land. Also benefits re: electricity costs, flood control, road upgrading, & demand for new building **(Redacted)** - Construction of first road to Runga in 2015 is locally significant **(R2, R7)**	- Dobhi over the last 20-25 years has experienced much construction & an increased transition from grain to apple orchards **(Do3)** - Some awareness of HEP: more concerned about large dams than micro HEP, consider greatest benefit is to distant energy consumers. Concerns of impacts on stream outflows used in agriculture & by households **(Redacted)**

Archives/ Observation: *(A, O)*

Interview Bulang (B): ***B3*** *Farmer- male*

Interview Dawara (Da): ***Da1*** *Apple farmer- male;* ***Da5*** *Tailor- male;* ***Da7*** *Shopkeeper- female;* ***Da8*** *Shopkeeper- male*

Interview Dhara (D): ***D3*** *Housewife in Phojal in 1994*

Interview Dobhi (Do): ***Do1*** *Hoteliers- 3 brothers;* ***Do2*** *Retired Indian Army Officer- male;* ***Do 3****- Buddhist family- females;* ***Do4*** *Tibetan settlement- male;* ***Do6*** *Dobhi family;* ***Do7*** *Farmer- male;* ***Do8*** *Housewife;* ***Do9*** *Tibetan Official- male*

Interview Phojal/ Runga (P, R): ***P1*** *Shopkeeper- male;* ***P2*** *Family 1;* ***P3*** *Family 2, with matriarch (>90 years);* ***P5*** *Head village- male;* ***P6*** *Female gathering;* ***P14*** *Family 4;* ***P15*** *Tea-shopkeeper- male;* ***P16*** *Temple workers- male;* ***P17*** *Elderly couple;* ***P18*** *Farmer- male;* ***P19*** *IT-shopkeeper- male;* ***R2*** *Farmer- male;* ***R4*** *Farmer- male;* ***R5*** *Farmer- male;* ***R6*** *School cook- female;* ***R7*** *Primary teacher- male*

Table 2

Capital Type	Capital Indicators	Runga & Phojal
Economic	**Income Sources & Diversity** *E1*	- Some with multiple sources (e.g. shop keeper: shop, taxi services & property letting/ construction) **(D1, P1, R6, R7)** - Agriculture dominated, for subsistence & trade (apple horticulture especially) **(P1, P2, P6, P13, P14, P17, P18, R1, R2, R4, R5)** - Other: tourism **(P1)**; government construction (females) **(P1)**; traditional crafts in spare time: women (socks & fabric), men (baskets) **(P1, P6)**; teaching/ school support **(P6, P7, P11, P12, R6, R7)**; government pension **(P6)**; IT/ mobile phone shop **(P19)**
	Female Financial Empowerment *E2*	- Women working as government labourers, are now paid direct to their bank account to prevent contractor deductions & encourage saving **(P1)**
	Financial Services Availability *E3*	- Bank in Phojal- In 2013 savings accounts for all (with 2 Lakh Rs government compensation limit). Loans (18-70 years, Indian Nationals): [1] Poor persons loan (0.15 Lakh Rs, 4% APR, 5 years, no guarantee); [2] Car/ taxi loan; [3] Farmers loan (3-20 Lakh Rs, 3 years, guaranteed by apple trees). Following 1994 flood- issued few loans & made no charitable donations **(P4)**
	Infrastructure (Buildings) *E4*	- Traditional build is small, wood/ stone walls & tiled roofs; new build is reinforced concrete/ brick **(O, P3, P6, P18, R1, R4, Online Resource 1, Figure 2 d)**
	Infrastructure (Communications) *E5*	- Services: Phojal Post Office **(A)**; IT education/ hardware/ software shop **(O)**; PC use is rare, with younger bias **(O, P1, P19)** - School IT/ internet provision: Yes in private primary, but no internet/ social-media teaching **(P12),** no in state middle **(P5, P7)**. Personal internet access/use is rarer (In 2015 & 2016, Yes: **D2, D5, P2, P19, R4** ; No: **P1, P6, P11, P14, P15, P16, P17**, **P18, R5, R6, R7)** - Satellite TV, mobile phone coverage/ wide use (but not some of elderly) **(D5, O, P1, P2, P6, P11, P14, P15, P16, P17, P18, P19, R2, R4, R5, R6, R7)**
	Infrastructure (Road/ Bridges) *E6*	- Local road improvements (new build and resurfacing) **(O, P1, R2)** part paid by local taxes **(P5)** - Phojal has a daily bus service to the Kullu Valley (0900,1700) **(P1, R6)**; some are too scared to use, preferring to walk **(P3)**
Social	**Societal Structure (Caste, Gender, Leisure)** *S1*	- Caste system prevalent in mountains- higher caste will not go into lower caste house/ drink water from them; lower caste cannot enter higher caste temple in Phojal **(P1)**, but other temples open to all **(R2)** - Male births are celebrated more **(P1)** - Boys play cricket & hunt in the snows; girls learn about stitching & weaving; & adventure sports **(P1)**
	Community Networks *S2*	- Help each other in the repair of houses **(P1),** women's gatherings **(O, P6)**, share knowledge on responding to weather impacts on crops **(R5)**
	Governance & Corruption *S3*	- Pradhan- Head of the local Panchayat (Phojal & 5 other villages) democratically elected by local people for a 5 year term **(P5)** - Concerns exist about HEP consent/ compensation processes due to alleged non-adherence to government terms & conditions, & also limited work opportunities for local communities **(Redacted)** - Panchayat seen as key local organisation for hazard event response, rather than by independent action **(D5, P18, R4)**
	Health *S4*	- Phojal has a doctor, medical dispensary & runs health awareness programmes (STDs, Illegal drugs) for children >10 years **(P5)** - Birth rates have declined with education: previously 5-6 **(**e.g. **P3)**, now 1-2 **(**e.g. **P1)**. Vasectomies now undertaken contrary to traditional views, which express concern if have no male offspring, as once considered a sign of a weak family **(P1)**
	Education *S5*	- National right to free education **(O** of slogans**)**, but attendance is still poor; teachers advocate value of education to parents **(P6)** - Education facilities supported by the local Panchayat **(P5)**, with primary schools in most villages and middle school in Phojal **(N1, R2)** - Approach is highly disciplined, militaristic- including oaths to respect people (parents & elders) & pledge to die for the Indian nation **(O)** - Aspiration/ advertising for higher education & professional careers **(O, P7),** and family members studying at University **(R5)**
Environmental	**Local Water & Sanitation** *En1*	- Village water stations in both villages (laundry, personal washing, animal drinking), water butts on houses **(O, R2)** - Public toilet in Phojal **(O)**
	Local Food & Energy Supplies *En2*	- Vegetable & fruit growing- when yields reduced by weather use products frugally; local café & shops with local and imported products **(O, R2, R4, R5)** - Electrical power lines and local supply into villages **(O, R3)** & also use of wood for burning **(P3, O)**
	Hazard & Risk Management *En3*	- *Community awareness of hazards:* A collective knowledge of 1994 flood key attributes: event timing & rainfall conditions; hillslope failures; slope-channel coupling; channel flow processes; physical impacts on the channel corridor & infrastructure **(D1, D3, D4, D5, N1, P1, P2, P5, P8, P9, P10, P15, P16, P18, R1, R2, R3)**. A strong belief in divine control **(P2, P5)**, and fear of future events & their impacts **(D1, P1, P2, P5, P13, P14, P18)** - *1994 event coping strategies*: [1] Responses- evacuation of houses and mills **(P1, P13)**, torch light/ lamp searches **(P1, P2, P4, P10)**; [2] Recovery- food sharing & community financial self-help **(P5)**, Phojal school closure for 10 days, to reduce pressure on access during initial clean up **(N1)**, compensation requests **(P1, P2, P5)** and insurance claims **(D4)** - *Mitigation & preparedness since 1994:* Tree planting **(R1, D2)**; gabion basket/ wall channelization **(D1, O, P1, P5, P10)** and boulder/ mud removal **(N1, P1, P9, P10)**; evacuation route signs, important telephone numbers, education posters at the middle school **(O, Figure 3)**; information about earthquake response/ landslides, but no syllabus to enable learning **(D2, D5, P5, P7, P19)**; landuse/ ownership mapping- initially avoiding re-building along the channel corridor **(A, D4, P1, P14, Figure 3)**; local Panchayat has no risk management plan as has insufficient money **(P5)**; middle school has no emergency response facilities other than water, nor sees the need for communications redundancy (e.g. radios) **(P7)**; public education/ event awareness/ weather forecasting via TV **(D5, P1, P18, P19)** and mobile phone apps **(P19, R4)**

Archives/ Observation: ***(A, O)***

Interview Dhara/ Neri (D, N): ***D1*** *Shopkeeper in Phojal- male;* ***D2*** *Phojal student;* ***D3*** *Housewife in Phojal in 1994;* ***D4*** *Owner in Phojal in 1994;* ***D5*** *Unspecified Phojal male;* ***N1*** *Head village, at Phojal School in 1994- male*

Interview Phojal/ Runga (P, R): ***P1*** *Shopkeeper- male;* ***P2*** *Family 1;* ***P3*** *Family 2, with matriarch (>90 years);* ***P4*** *Bank Manager- male;* ***P5*** *Head village- male;* ***P6*** *Female gathering;* ***P7*** *Middle Sch. Head- male;* ***P8*** *Phojal woman with fodder;* ***P9*** *Miller- male;* ***P10*** *Miller- male;* ***P11*** *Family 3;* ***P12*** *Primary teacher-female;* ***P13*** *Farmer, male, parents Millers;* ***P14*** *Family 4;* ***P15*** *Tea-shopkeeper- male;* ***P16*** *Temple workers- male;* ***P17*** *Elderly couple;* ***P18*** *Farmer- male;* ***P19*** *IT-shopkeeper- male;* ***R1*** *Farmer male;* ***R2*** *Farmer- male;* ***R3*** *Head village- male;* ***R4*** *Farmer- male;* ***R5*** *Farmer- male;* ***R6*** *School cook- female;* ***R7*** *Primary teacher- male*

Table 3

Capital Type	Capital Indicators	Bulang, Dawara & Dobhi
Economic	**Income Sources & Diversity** *E1*	- Some with multiple sources (e.g. family hotel & government teacher) **(Do1)** - Other single income: army pension **(Do2)**; farming & sales **(Da1, Do7, Do8)**; government teachers **(Do1, Do3)**; labouring **(Da2, Da 4)**; shopkeeper **(Da7, Da 8)**; tailor **(Da5)**; Tibetan handicraft merchant across India **(Do4)**; Tibetan Official **(Do9)**
	Financial Services Availability *E3*	- ATM in Dawara alongside NH-21 road **(O)**
	Infrastructure (Buildings) *E4*	- Mix of traditional & modern (brick/ reinforced concrete) styles; but more modern & higher density types **(O)** - Ad hoc Nepalese buildings alongside Phojal Nalla **(O, Online Resource 1)**
	Infrastructure (Communications) *E5*	- Dawara & Dobhi Post Offices **(A)** - Satellite TV, mobile phone coverage **(O, Do8, Do9)** - Personal internet provision mixed **(**In 2016, Yes: **Do9** [c. 60% of Tibetan commune]; No: **Do8)**
	Infrastructure (Road/ Bridges) *E6*	- Extensive road network, including resurfaced NH-21 (2014) & diverse traffic types **(O)** - School bus services to Katrain **(Da5, Da8)** - New footbridge to replace bridge lost in 2011 monsoon flood **(B1)**; more robust than temporary tree trunk crossing **(O)**
Social	**Community Networks** *S2*	- Growing Tibetan community (2016: c. 67 families/ 300 people; 140 buildings, including a community hall) & Kullu district head office on the Dobhi Fan commune (25 Bighas or 4 ha). Some additional short-stays following *'Losar'* (New Year) for spring/ summer trade **(Do4, Do9)**. - Nepalese migrant community at Dawara of c. 30-35 people, 6 families **(Da4)**. Also Nepalese migrants work on HEP projects, they live on site or in Patlikuhal; spend 6 months in the Kullu Valley, before returning to Nepal to farm **(B2, Da4, O)** - In Dobhi is a wide belief that 'whole globe is one village' so is equality irrespective of religion **(Do1)** - Residential care home, NGO funded, with residents from all over India, of which 20% have to be local **(Do5)**
	Health *S4*	- Offspring/ sibling frequencies are variable, of those interviewed: 1 **(Do8)**; 2 **(Da5, Do6)**; 3 **(Da3)**; 4+ **(Da6, Do1, Do4)**
	Education *S5*	- Mixed attitude to free education amongst the Nepalese community: children attend & also do more at home **(Da2)**; children don't attend as needed to work **(Da3)** - Few children in Tibetan commune, so travel to nearby Tibetan schools in Manali and Bhuntar **(Do9)**
Environmental	**Local Water & Sanitation** *En1*	- People washing fabrics & themselves, swimming & defecating in Phojal Nalla **(O)**. Now considered too dirty to drink **(Da9)** - Water butts on roofs **(O)**
	Local Food & Energy Supplies *En2*	- Vegetable & fruit growing; many local cafés & shops with local and imported products **(Do3, Do6, O)** - Milk from local cows **(Do8)** - Electrical power lines **(O)** & also use of wood for burning **(O)**
	Hazard & Risk Management *En3*	- *Community awareness of hazards:* Variable knowledge of specific flood events: no knowledge **(Da9, Do2, Do3, Do6)**; Phojal Nalla flood in 1894 **(B3, Do1)**, 1994 **(Da1, Da6, Da7, Da8, Do8)**; Beas River flood in 1998 & its impacts **(Da5, Do4, Do7)**. Beliefs include- lack of warnings, helplessness, controlled by God, is largely a problem for the upper catchment & not Dawara **(Da1, Da6, Da7, Da8, Do8)** - *Mitigation & preparedness:* Nepalese family appreciates they are illegally settled & exposed to floods, hence would move away in the event of a flood **(Da2)**. Tibetan commune aware of flood hazard, but purchased this low-cost location owing to budgetary constraint **(Do9)**. Subsequently gained consent for the construction of self- funded (40 Lakh Rupees) flood walls following the Beas River flood of 1998, with awareness they have a design limit; so residents fear remains **(Do4, Do9 O)**. Public education/ event awareness/ weather forecasting via TV **(Do8, Do9)**. Awareness of district government evacuation orders to safe areas during floods, but perceive personal safety and inapplicability of such measures **(Do8)**.Children are advised to stay away from rivers during the monsoon season **(Do8)**

Archives/ Observation: ***(A, O)***
Interview Bulang (B): ***B1*** *Stonemason alongside Phojal Nalla near Bulang- male;* ***B2*** *Nepalese workers at HEP sub-station- male;* ***B3*** *Farmer- male*
Interview Dawara (Da): ***Da1*** *Apple farmer- male;* ***Da2*** *Nepalese family 1;* ***Da3*** *Nepalese family 2;* ***Da4*** *Nepalese family 3;* ***Da5*** *Tailor- male;* ***Da6*** *Woman carrying grass;* ***Da7*** *Shopkeeper- female;* ***Da8*** *Shopkeeper- male;* ***Da9*** *Café customer- female*
Interview Dobhi (Do): ***Do1*** *Hoteliers- 3 brothers;* ***Do2*** *Retired Indian Army Officer- male;* ***Do3*** *Buddhist family- females;* ***Do4*** *Tibetan settlement- male;* ***Do5*** *Residential care home owner- male;* ***Do6*** *Dobhi family;* ***Do7*** *Farmer- male;* ***Do8*** *Housewife;* ***Do9*** *Tibetan Official- male*

Online Resource 1: The Phojal Nalla catchment and fan complex, as seen from near Jana [November 2016]. Inset:
(a) Phojal- indigenous village footprint, inclusive of temples, on a forested hillslope above Jawala Mukhi Nalla [18 October 2013];
(b) Informal Nepalese dwellings immediately alongside Phojal Nalla at Dawara [15 April 2015].

Online Resource 2: Hydro-climatic conditions.
(a) Climate at Naggar Farm [Jangra and Singh 2011];
(b) Flow at Dobhi Bridge [BEHEPD 2009]

Attributes	Characteristics	Reported Details
Rainfall (a) (1962-2009)	*Mean annual rainfall*	- 1124 ± 248 mm (1σ) - No significant change over time series, but increased frequency of extremes & inter/intra annual variability
	Wettest months	- July (160 ± 82 mm, 1σ) - August (156 ± 78 mm, 1σ)
Temperature (a)	*Decadal annual value change (1961-1970 to 2001-2009)*	- Max. (20.6 to 21.4 °C) - Min. (8.8 to 11.7 °C) - Mean (14.7 to 16.7 °C)
Channel Discharge (b) (1967-1983)	*Gauged flow*	- Perennial - 0.63- 41.27 $m^3 s^{-1}$ - Peaks: May to August

(a): IARI-RS 'Katrain' [Indian Agricultural Research Institute] data recorded at Naggar Farm, c. 1660 m ASL, c. 7.2 km ENE of Phojal village

(b): Phojal Nalla gauging at Dobhi Bridge, c. 1490 m ASL, 3.7 km channel distance from Phojal village

Attributes	Characteristics	Reported Details
Hydro-meteorology	*Prior to convective storm*	- 2 days prolonged rainfall in Phojal
	Storm continuity	- Two episodes of heavy rainfall
	Storm timing	- c. 2200 IST 9 August 1994 to c. 03:00 IST 10 August 1994 (IST- Indian Standard Time; +5:30 UTC)
	Storm duration	- 0.5- 3 hours
Geomorphic Responses	*Hillslope failures*	- ≥ 3 locations upstream of Phojal - High pasture at Jeydahr (c. ≥ 160 m^3) - Stream side slope near Runga
	Slope-channel coupling	- At least 2 locations, including via forested slopes
	Sediment, woody-debris & water transfer	- 8.1 km distance - Highest source: Jeydahr (Lat. 32° 5'1.24"N, Long. 77° 4'4.72"E, c. 2620 m ASL) - Terminus: Phojal Nalla/ Beas River confluence (Lat. 32° 5' 16.28"N, Long. 77° 8'5.90"E, c. 1415 m ASL)
	Event flow processes	- Fluvial & potentially debris flow - Recorded impact in Phojal village (c. 1765 m ASL) at c. 02:30 IST 10 August 1994
	Post-event channel discharges	- Elevated flow & sediment loads for 2 days
Natural & Community Physical Impacts	*Human fatalities*	- Estimates range 7-30, but 11 commonly given
	Loss of buildings	- Residential properties (*n*= 4) - Water/ flour mills (*n*= 5) - Temporary stalls (*Khokhas*) (*n*= 21) - Included shops, health centre and veterinary dispensary
	Loss of vehicles	- 3; one found 22 days later in the Beas River down valley at Kullu (> 20 km)
	Road & bridge damage	- Severing of 100-150 m of local road into Phojal village, over a disputed period - Road bridge damage (but not loss)
	Loss of trees	- Forest (*n*= 1200-1500) - Orchards (*n*= 75-100)
	Loss of horticultural land and produce	- c. 4-5 to 20 ha - Boxed up apples on a truck
	Loss of livestock (sheep & cows)	- Jeydahr pasture (number not known- veterinary records lost in a 1995 Beas River flood at Patlikuhal)

(Based on a synthesis of data reported by: The Tribune 1994; Singh et al. 1994, 1997; Kuniyal et al. 2004; Bhatt and Bhargava 2006; Gardner and Dekens 2007; Brakenridge 2014; Johnson et al. 2014)