interAlpine USA

Climate Change, Snowpack Distribution and Highway Winter Maintenance

Submitted by:

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Project Duration:
Phase I: Conceptual Introduction and Charrette – **One Year** from Authorization to Proceed
Phase II: Implementation Trial on Selected Roads in Wyoming, and if warranted, SDM application expanded to include other regional DOT's mountainous roadways, **Three Years** from the end of Phase I.

Costs:

(Phase I)	$ 45,580.00
(Phase II)	$142,620.00
Total Costs, all Phases:	$188,200.00

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PROBLEM STATEMENT

No one argues that it isn't happening. Winter snowpacks in the Rocky Mountains are a fraction of what they used to be in decades past. It rains when it used to snow. Snowline is higher. South and west facing aspects no longer hold snow through-out the winter, and peak snowmelt runoff is smaller in volume and earlier in the spring than it used to be. All this is of grave concern to water supply hydrologists working in watersheds and basins where winter snow is the primary precipitation mode.

Transportation agencies are similarly challenged. Like water supply, flood control, coastline protection, and the emergency management of tornados, hurricanes and winter storms; there are few public works activities more inextricably linked to climate than highway winter maintenance.

From the cohort noted above, each is challenged to plan, expend, build and maintain for a nature that is serving up something different than it used to. That's the Climate Change Challenge. How to plan for a future that will be something different than the average of the past? Public Works of most every kind are at the tip-of-the-arrow on much of this.

Specifically, this challenge impacts highway winter maintenance as DOT planners, managers, foreman, and operators seek valuable information on climate's "new normal" for winter snow amounts and distributions in their annual work plans, budgeting cycles, and capital purchases.

Phase I of this project, over a duration of one year, will investigate a novel, state-of-the-art snowpack distribution model (SDM), developed initially for annual snow water storage estimates, for its value and utility as a tool in winter maintenance planning and operations, where climate change is resulting in different amounts and distributions of winter snow than in the past.

Like planning itself, the Phase I research question of "value and utility" has a subjective element that needs to be informed by the opinions of the same end user group; WYDOT's winter maintenance planners and practitioners. Hence, the research work plan for this investigation is collaborative, and includes provisions for interaction with WYDOT's research and winter maintenance staff cohort to help develop an answer to the following Phase I question: Is there value and utility in SDM runs for past years and various regions of Wyoming, as well as possible future scenarios? Can and will this information support and improve winter maintenance planning and operations under the influence of climate change?

The Phase II research question takes up the challenge of implementation of SDM, at a practical scale for what showed promise in Phase I as a valuable tool in winter maintenance planning and operations. Engineering research is fortunate to have a relatively simple experimental design at this juncture – give it a try at a reduced scale.

Phase II of this investigation would take up the following Tasks of an Implementation Trial: One, run a suite SDM's for both historic and real time for winter roadways selected under advisement from WYDOT for their potential to be able to use this information valuably in an operational setting, and Two, with advice from WYDOT planners, interject SDM runs into the WYDOT winter maintenance planning processes, initially and particularly those of medium and long terms, and assess their potential value to these planning processes.

BACKGROUND STATEMENT

InterAlpine developed and implemented its Snowpack Distribution Model (SDM) in support of the work of snow hydrologists and water supply entities trying to better understand the impacts of climate change on annual snowpack distributions and the resulting snow water volumes available for water supply uses [1, 2].

The InterAlpine SDM is evolutionary in its development, and has been improved over the years to include all the computational power and efficiency available in modern Geographic Information System (GIS) programming, processing and visualization.

As an example, Figure 1. shows the difference between the snowpack of April 1, 1980 and the 30 year average April 1st snowpack for the Central Wasatch mountains of Utah. Those portions of this model run that are in darker blue or green are places where the snowpack is in excess of the 30 year average. Conversely, those portions of this model run that are in light blue to burnt red are where the snowpack is below the 30 year average. 1980 was a "good" water year. "SWE" is snow hydrology vernacular for Snow Water Equivalent.

On the other hand, Figure 2. depicts this same difference between the 30 year average snowpack and the April 1, 2015 snowpack. Unlike 1980 and similar to many of the more recent years, 2015 was in a serious climate change driven drought. In 2015, anywhere you went in the Central Wasatch highland, at that spot, the snowpack was well below the average.

What is illustrated is that the InterAlpine SDM allows one to examine, at scales much smaller than the watershed itself, the fine detail in the distribution of a snowpack at any given point and any juncture in time.

Characteristics of the snowpack distribution that are germane to highway winter maintenance planning and operations, such as snowline, thinned or melted out areas, and maximum snow depths are easily seen, especially when coupled in GIS with the highway system footprint.

More importantly, the impact of climate change on snowpacks and their distribution can be compared to snowpacks from before the onset of climate change, as well as model runs of virtual (and most likely extreme) events that *may* happen in the future. If this information has value and utility, winter maintenance planning activities and operations can be conducted with these climate change impacts in mind.

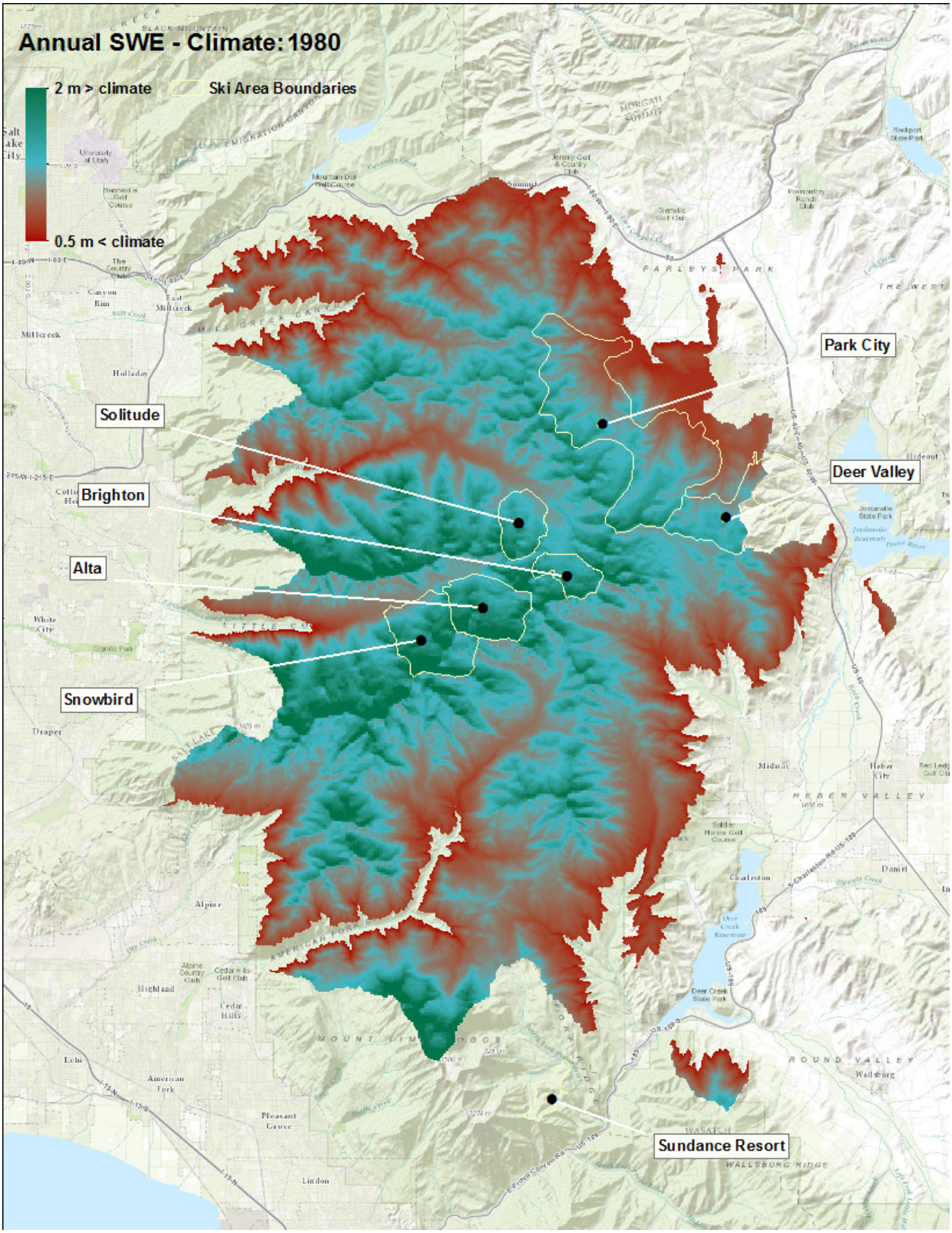

Figure 1. The difference between the April 1, 1980 snowpack and the 30 year average snowpack for the Central Wasatch mountains, Utah.

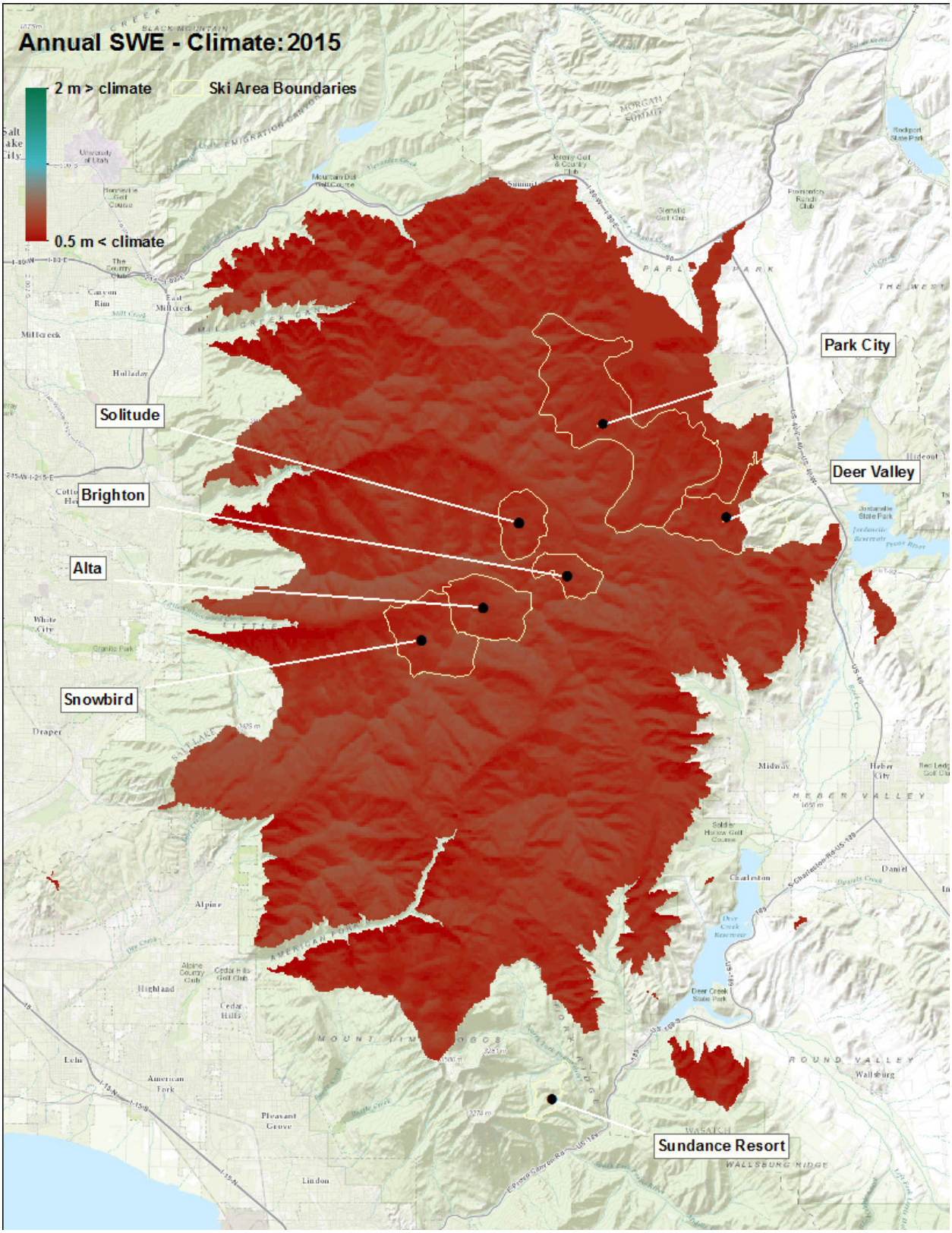

Figure 2. The difference between the April 1, 2015 snowpack and the 30 year average snowpack for the Central Wasatch mountains, Utah.

OBJECTIVES

Output Measures

Phases I and II of this research addresses the Transportation Research Board's (TRB) Standing Committee on Winter Maintenance (AHD65) strategic goal of a better understanding of the "geographical distribution and management of winter precipitation (frost, ice, snow, fog) and frozen ground, and their impact on road safety, traffic flow and traffic control". This is one of four overarching outputs of the TRB Winter Maintenance Committee's research strategy.

Similarly, both Phases of this research are well matched to WYDOT's own Research Center goals, including "improving the existing transportation system" through more effective and cost efficient winter maintenance planning and operations, as supported by a better understanding of snowpack distributions that reflect changes due to on-going climate change. In addition, this research also supports WYDOT's Research Center goal of "enhanced safety on the transportation system".

Outcome Measures

This investigation is cast in two (2) Phases. This is done so that the outcome of Phase I informs whether or not to invest further in Phase II. There would be no reason to pursue a Phase II Implementation Trial of a technology or methodology that did not find value with its target end user groups in a Phase I conceptualization and vetting.

Hence, critical to Phase I of this investigation is this outcome: Can snowpack distributions that are being dramatically modified by climate change be modeled with the InterAlpine SDM with sufficient fidelity and timeliness to be valuable for winter maintenance planning and operational decision making purposes? This is the primary measure of a successful outcome to Phase I of this investigation. In Phase I we will have searched for and discovered the value and utility in modeling snowpack distributions that are indicative of a "new normal" in climate to the degree that winter maintenance planning and operations are better informed, more effective, more cost efficient, and the resulting winter roadway levels of service are improved.

The Phase II outcome is eloquent, and it can be distilled to this: Can a promising technology or methodology, in this case SDM's under climate change in support of winter maintenance planning and practice, successfully find their places in practice and practical settings? The bone yard of research is filled with ideas, concepts, materials, and facilities that looked good to everyone after some thoughtful consideration, but they couldn't clear the hurdle into implementation. Here's the good news, though, a full bone yards means many good attempts, and the more you try, the more often something that does go on to make a difference happens.

The Phase II outcome for this investigation will be indicated by whether or not at the end of the three year Implementation Trial period, there are specific efforts on the part of WYDOT and other DOT winter maintenance planners and practitioners to have this information on snowpack distributions under the influence of climate change in their planning and work processes on an on-going basis.

Goals

The primary goals of Phases I and II of this research are to: One, establish the value and utility of modeled snowpack distributions under climate change, such that they effectively inform winter maintenance planning and operations, and Two, via Implementation Trials, see if this new information can be successfully implemented in WYDOT's regular winter maintenance planning and operations entities and activities.

Performance Measures

The leading performance measure of Phase I of this research will be new consideration given to modeled snowpack distribution in highway winter maintenance planning and operations. Phase II will examine in detail, via Implementation Trials, the structure and mechanisms by which this new information source can be considered and integrated into specific winter maintenance and transportation planning and operations activities. The leading Phase II performance measure will be the resulting desire and pressure to have this information in WYDOT and other DOT's winter maintenance planning and operations communities and activities on an on-going basis, after the duration of all Phases of this investigation have expired.

BENEFITS

If both Phases of this investigation can bear out that modeled snowpack distributions under the influence of climate driven change has value and utility in winter maintenance planning and operations, then the benefits will include better informed planning that is more effective, more cost efficient, and results in improved winter roadway levels of services.

APPLICABLE QUESTIONS

One "potential barrier to implementation" is: Does the winter maintenance planning and operational culture of WYDOT (and other DOT's) have mechanisms in place to practically and effectively utilize information on annual snowpack distributions that are different from those in the past due to climate change?

The "time frame for implementation" would be in years two, three, and four (Phase II) of the investigation.

There is no Federal Land NEPA requirement for this research.

There are few, if any, "uncontrolled" factors. These investigations revolved primarily around the actual snowpack modeling, and human consideration, discussion and synthesis surrounding these simulations and model runs of a natural system that we are not, otherwise, going to intruding upon.

There is no "Buy America", confidentiality, copyright or trademark issues surrounding this research, or its data and report products.

STATEMENT OF WORK

Workplan and Scope

Phase I, Concept Introduction and Charrette:

Task 1
Upon Authorization-to-Proceed, InterAlpine, in collaboration with WYDOT Research and WYDOT State Maintenance Engineer's Office, will select and run the SDM for 12 to 18 separate regions, for multiple winters past, at various scales, and overlay WYDOT's highway system unto these model runs.

Task 2
A design charrette will be organized collaboratively with WYDOT Research and WYDOT State Maintenance Engineer's Office to garner the opinions of winter maintenance planners and practitioners on the value and utility, if any, of these SDM runs that will include both historic averages and more recent seasons that have been impacted by climate change for the same regions and sites.

As a prelude to the charrette activity, a briefing document well be prepared and circulated to those who will be in attendance that contains a statement of the charrette meeting goals, the SDM runs with an expanded explanation, and the range of questions that will be ask when we join in charrette to explore the value and utility in modeled snowpacks that are being impacted by climate change.

The design charrette will be organized and scheduled to take advantage of an existing WYDOT meeting where the WYDOT winter maintenance cohort of planners and practitioners are anticipated to already be in attendance. The charrette will not take more than an hour or two, including discussion.

Task 3
The results of the charrette will be summarized and circulated for accuracy and completeness. A synthesis of the conclusion of the charrette will inform whether or not there is discernable value and utility in SDM runs of snowpacks that are being impacted by climate change in WYDOT's winter maintenance planning and operations.

Phase II, Implementation Trials:

Task 4
Explore the details and mechanisms by which SDM runs of snowpacks under the influence of climate change can be effectively implemented in WYDOT's winter maintenance planning and operations. Specifically: One, run a suite SDM's for both historic and in real time for winter roadways selected under advisement from WYDOT for their potential to be able to use this information valuably in an operational setting, and Two, with advice from WYDOT planners, interject SDM runs into the WYDOT winter maintenance planning processes, initially and particularly those of medium and longer terms, and assess their potential value in these planning processes.

Task 5
Pursue focused opportunities to disseminate the successes and lessons learned by this investigation to other regional DOT's with mountain roadways for its potential to be valuable to them in the same way it has been for WYDOT, including generating some sample model runs of their roadways, at their request.

Task 6
The results of this research will also be reported out as a WYDOT Research Final Report, as well as at domestic (TRB Annual Meeting and attendant Transportation Research Record, amongst others) and international venues (PIARC, semi-annual International Winter Maintenance Conference, amongst others).

Workplan Schedule

Phase I of the investigation, will be completed in one (1) year from Authorization-to-Proceed. Phase II, with a duration of three (3) years, will commence upon completion of Phase I. Please consider Table 1., below, a Gantt chart depiction of this Workplan Schedule.

	Yr 1	Yr 2	Yr 3
Phase I			
Task One ----→			
Task 2			
Task 3			
		Phase II	
	Task 4 ----------	----------	----------→
		Task 5-----	----------→
			Task 6-----→

Table 1. Workplan Schedule for Phases I and II, InterAlpine Proposal to the WYDOT RAC, entitled; Snowpack Distribution, Climate Change and Winter Maintenance.

BUDGET

InterAlpine will complete both Phases of this project on a cost-not-to-exceed basis for $188,200.00, over a duration of four (4) year from Authorization-to-Proceed. A detailed budget breakdown, by task, is presented in Table 2., below.

Labor and Non-Labor Cost Summary	Rand Decker, PI	Senior GIS Programmer	Technician	Subtotals/Extensions
Billing Rate:	$141	$95	$55	
Phase I: Conceptualization and Charrette Vetting				
Task 1 - SDM runs	$8,460	$9,500	$1,100	$19,060
Labor: hours	60	100	20	
Task 2 - Design Charrette	$11,280	$1,900	$1,100	$14,280
Labor: hours	80	20	20	
Non-Labor Costs	Amount	QTY		
Travel - Arizona to Wyoming	$1,200	3		$3,600
Task 3 - Synthesis of Results and Reporting	$5,640	$1,900	$1,100	$8,640
Labor: hours	40	20	20	
Phase I, Labor and Non-Labor Costs, All Tasks				**$45,580**
Phase II: Implementation Trials and Dissemination				
Task 4 - SDM in Winter Maintenance Operations and Planning	$39,480	$38,000	$6,600	$84,080
Labor: hours	280	400	120	
Non-Labor Costs	Amount	QTY		
Travel - Arizona to Wyoming	$1,200	6		$7,200
Task 5 - Focused Application of SDM's in Neighboring States	$8,460	$9,500	$1,100	$19,060
Labor: hours	60	100	20	
Non-Labor Costs	Amount	QTY		
Travel - Arizona to Wyoming and Neighboring States	$1,200	4		$4,800
Task 6 - Dissemination and Technology Transfer	$11,280	$1,900	$1,100	$14,280
Labor: hours	80	20	20	
Non-Labor Costs	Amount	QTY		
Travel - Arizona to Wyoming	$1,200	2		$2,400
Arizona to TRB (Washington DC)	$2,400	2		$4,800
Arizona to International WM Conference and similar	$3,000	2		$6,000
Phase II, Labor and Non-Labor Costs, All Tasks				**$142,620**
Project Total, Labor and Non-Labor Costs, All Phases				**$188,200**

Table 2. Budget by Phase, Task and Totals for Climate Change, Snowpack Distribution and Winter Maintenance.

DATA MANAGEMENT PLAN

Name of Researcher	InterAlpine Associates, LLC. / PI: Dr. Rand Decker
Name of Project	Climate Change, Snowpack Distribution and Winter Maintenance
Funding Bodies	Wyoming Department of Transportation
Partner Organizations	None
Project Duration	48 months from Authorization-to-Proceed
Date Written	March 11, 2016
Date Revised	None, to date

Phases I and II of this project involve modeling snowpack distributions with the InterAlpine SDM for selected seasons and sites in Wyoming for the purpose of determining their value and utility in winter maintenance planning and operations.

The primary data that will be produced and stored from this project are map images of various regions Wyoming and an attendant overlay of the highway transportation system at that site. Data file formats are typically .JPEG and .PNG. This data will be stored, redundantly, on multiple InterAlpine workstations.

InterAlpine utilizes the following directory and file name structure:
InterAlpine → Client Name → Project Number → Subfolder → Date → format (docx, pdf, etc.)

No restrictions on data access are anticipated by InterAlpine. Only InterAlpine staff will have direct access to the workstations storing this project's data. At various times through-out this investigation, WYDOT Research and WYDOT State Maintenance Engineer's Office staff and others will have electronic copies of the resulting SDM runs and data.

Other researchers and interested parties may be granted access to these data files with WYDOT's approval. Other potential users include snow science researchers and engineers, WYDOT personnel, or other government officials with interests in the outcomes of the investigation. InterAlpine Associates, LLC and WYDOT possess joint ownership of the data.

LIMITATIONS

InterAlpine will perform these services in a manner consistent with the standards of care and skill ordinarily exercised by members of the profession, practicing under similar conditions and locations at the time the services will be performed. Acceptance of this proposal neither makes nor intends a warranty or guarantee, express or implied, nor does it create a fiduciary responsibility to WYDOT by InterAlpine.

REFERENCES

1.) Decker, R., and E. Schiefer, Why Snow can't Sit Still, "Dalmatian Terrain" and Modeling Snowpacks in Mountainous Terrain for Water Storage Estimates, Abstracts and Program, Workshop on Liquid Water in Snow, (Swiss National) Institute for Snow and Avalanches (SLF), Davos, Switzerland, April, 2014.

2.) Froyland, H., J. Stackhouse, E. Schiefer, and R. Decker, Modeling of Snowpack Accumulation and Losses in Mountainous Terrain for both Snowpack Storage Mapping and Watershed Storage Estimates, Proceedings of the 2013 Western Snow Conference, Jackson, Wyoming, April, 2013.