RESORTTAX
— BUILDING BIG SKY SINCE 1992 —

2018-2019 APPLICATION FOR RESORT TAX FUNDS

Applicant's Official Name: Gallatin County 911

Project Name: Big Sky Area Communications Upgrade Project

Address: 1705 Vaquero Parkway, Bozeman, Montana 59718

Representative: Captain Jim Anderson, Director

Telephone: (406) 582-2092 **Email:** jim.anderson@gallatin.mt.gov

Project Start Date: July 1, 2018 **Project Completion Date:** June 30, 2019

Total Funds Requested $ 938,344

State your estimated payment request schedule for the coming year; amounts should total funds requested. Please enter dollar amounts.

	July '18	Aug '18	Sep '18	Oct '18	Nov '18	Dec '18
Payment Request	$488,344	$450,000	-0-	-0-	-0-	-0-
	Jan '19	**Feb '19**	**Mar '19**	**Apr '19**	**May '19**	**Jun '19**
Payment Request $	-0-	-0-	-0-	-0-	-0-	-0-

I certify that the application and its attachments are correct to the best of my knowledge.

James G. Jore
Signature

COUNTY ADMINISTRATOR
Title (Board Chair or Governing Officer)

JAMES T. JORE
Printed Name

APRIL 30, 2018
Date

1) Provide a description of the entity and the Mission Statement.
State the entity's tax status/legal identity and when it was initiated.
What is the personnel makeup of your office; specifically how many are employees, how many are contractors and what are their duties? What is the full time equivalent (FTE) of each: ¼ , ½, ¾ or full time?
Unless previously provided to the resort tax office, please include a copy of the Articles of Incorporation.
(200 words max)

Gallatin County 911 is a division of the Gallatin County government and was formed to provide dispatch and communications services for all emergency services in Gallatin County. In the Big Sky area, Gallatin County provides 911 telecommunication services, emergency incident paging and emergency services radio communications, in both Madison and Gallatin County, for the Big Sky Fire Department and the Gallatin County Sheriff's Office, along with other associated agencies such as the Montana Highway Patrol.

The Gallatin County 911 Director is directly supervised by the Gallatin County Administrator and, to a lesser extent, the 911 Advisory Board, which is made up of 7 public safety and community members who serve in an advisory capacity in support of the division's goals through interaction with the 911 Director and the County Administrator. The Advisory Board is the mechanism that allows the Big Sky Fire Chief and the Gallatin County Sheriff direct access to guide Gallatin County 911 in meeting the needs of the Big Sky community.

Gallatin 911 is slated to have 25 full time employees involved in the delivery of the above listed services and administer the organization.

Mission Statement: We are dedicated to providing prompt, efficient and progressive emergency communications service to the citizens of the communities we serve.

2) Provide a complete description of the project(s). Include the project(s) purpose, goals and objectives. For each project provide a budget number and measurable objectives, i.e. how you will do something and in what timeframe. The information provided here should be specific regarding what the entity is requesting to be funded by resort tax. If requesting funds for operations, identify the categories and assign a dollar amount (salaries, software, etc.) If permits are required, please specify what permits are required and what projects they apply to. If requesting funds for a study (feasibility, etc.), a minimum of two bids are required. Also provide the RFP submitted for the study. Funding for a study will only be considered if the proposal has measurable outcomes. Please be succinct.

Gallatin County 911 is asking for financial support for capital expenditures to address a 40 year problem with emergency services in Big Sky. Currently, emergency two-way radio communications in Big Sky are served by two mountain top radio transmitters (one in Madison County on Andesite Mountain and the other in Gallatin County on Eaglehead Mountain, each utilizing the same radio frequency) and one of them requires solar power as it is otherwise inaccessible for utilities.

Due to previous radio system failures, these radio repeaters connect to Gallatin County 911 via a tenuous phone link to a radio in Big Sky Fire Station 1. This link is very unreliable and is prone to failure as the phone link passes through several carriers to reach the dispatch center. It should be noted that other Madison and Gallatin County emergency services do not use this part of the system as it is solely used in the Big Sky area.

The radio frequencies that are utilized fall within the VHF band, which gives a transmission greater range but does not penetrate buildings very well due to the size of the frequency wavelength. This causes serious safety problems for emergency responders as they cannot reliably hear or communicate with 911 Dispatch within buildings, which can not only hamper the ability for them to call for help but also cause them to miss updates coming from Dispatch during serious, in-progress/evolving incidents.

Similarly, the emergency paging system (which is a different radio than what is used for two-way communication) is hosted in Big Sky Fire Station 1 via a phone link. It not only faces the same reliability issues but is limited in its performance, as the transmissions come from the antenna on top of the station and are blocked by surrounding hills, severely reducing its range. The paging system is used by both the Big Sky Fire Department and the Gallatin County Sheriff's Office.

A 2015 study was conducted by Gallatin County to better understand all of the communications issues, including those in Big Sky. To fix all of the identified shortcomings would cost well in excess of $20 million countywide, which is not economically feasible. Because of this, the plan has been reduced to phases, one of them being to create a robust and redundant two-way radio system and improved paging system in Big Sky.

To correct all of the aforementioned issues, the following is proposed:

i) Create a multiple channel 800 MHz mission critical radio network based on Lone Mountain. This gives the radio system a greater range due to the radio tower height, also allows for building penetration as it uses a smaller wavelength and gives local responders the ability to use multiple radio frequencies rather than the one they share now.

   The Lone Mountain site was also chosen because it would allow for the radios to be linked to Gallatin County 911 Dispatch in Bozeman via a dedicated microwave link, instead of a phone line. The proposed microwave link routes through Virginia City before going through other existing sites back to Bozeman and would be linked to the state-wide microwave network. This is a much more stable and reliable system.

   The positioning of the site on Lone Mountain also allows for an unlicensed microwave hop from the mountain to the Big Sky Fire Station and Sheriff's office to provide real-time data communications services. In addition, a faster speed fiber optic network will be installed to provide primary data and internet services to the Big Sky office. This will provide redundant communications services which do not exist today.

   (1) Gallatin County has submitted a Homeland Security Grant through the State of Montana has been requested for portions of this project. Should it be awarded, it would reduce the below request by $250,000.

   The amount requested for this portion of the project is $488,344.

ii) To be able to utilize the improved radio system, the Big Sky Fire Department and the portions of the Gallatin County Sheriff's Office that serve the Big Sky area would need to purchase new "dual band" radios that allow emergency responders to use the new 800 MHz system while maintaining the ability to use the VHF band found in our mutual aid partners. This would require the purchase of 34 mobile (vehicle mounted) and 33 portable (hand held) radios.

   NOTE: The Big Sky Fire Department was previously able to use funds from district savings to pay for 10 portable and 4 mobile dual band radios, thus reducing the above request.

   (1) The Big Sky Fire Department has requested a Federal Emergency Management Agency Assistance to Firefighters Grant to fund the purchase of radios for BSFD. Should it be awarded, it would reduce the below request by $300,000.

   The amount requested for this portion of the project is $450,000.

3) Is the project within the resort tax district? (25 words max)

This project is for funding a radio system dedicated to the Big Sky area, serving the entirety of the resort tax district and a data network solution dedicated to the First Responders in Big Sky.

Please note: Not every project will fulfill questions #4 through #8. Applications will not be rated on the ability to fulfill multiple questions.

Does the entity and/or project...

4) Benefit the community at large including residents, visitors and tax collectors/the business community? (50 words max)

Adequate local emergency services are the foundation of a healthy and thriving community. If Gallatin 911 does not support GCSO and BSFD it would have a negative impact on all aspects of our community, including local residents, visitors and the business community.

It is the mission of Gallatin County 911 to provide mission critical, emergency services communications to the First Responders of Big Sky and the greater Big Sky community. This project will improve the reliability and performance of the services we provide and thus create a safer community for the residents, businesses, and visitors of Big Sky.

5) Promote tourism development, help make Big Sky a world class resort community and increase the visitor experience and/or increase resort tax revenue? (50 words max)

Gallatin 911 supports GCSO and BSFD by providing a high standard of emergency services expected in world class communities. Without the presence of effective local emergency services providers, future development would not be possible, which would limit growth and negatively impact resort tax revenue.

Improved radio communications will increase our ability to provide a high standard of mission critical communications and provide for increased safety of our First Responders and a safer environment for the public. People will travel to and make plans to enjoy a location in which they feel safe and protected by emergency services thus potentially increasing resort tax revenue.

6) Support, improve or maintain critical infrastructure, public health, safety and/or welfare in the world class community? (50 words max)

Together, GCSO and BSFD are a large component of the critical infrastructure of the Big Sky community and are relied upon to respond to emergency incidents, including vehicle accidents, in-progress crimes, emergency medical calls, rescues, fires, among other needs. GCSO and BSFD are heavily dependent upon Gallatin 911 to provide these services.

7) Involve collaboration among entities in the community to meet common goals? (100 words max)

Gallatin 911 supports GCSO and BSFD in their collaboration with the over 100 homeowner associations, property management companies, developers and business owners to promote a community that is safe, compliant with national standards and that is robust and sustainable.

8) Fill a community need not currently or adequately being satisfied? (50 words max)

There are no other entities to provide the services that Gallatin 911, GCSO and BSFD provide in this community. These departments are critically important components to the safety of Big Sky and all people who live, work, and play in the greater Big Sky community.

We are asking for help in funding long-term improvements that are much needed and will continue to

serve the community for years to come. This is a one-time investment in the continued mission critical services provided in Big Sky.

9) What is your entity most proud of accomplishing? (100 words max)

Gallatin 911 has a long standing, proud tradition of service to the Big Sky community. This is far from just performing tasks when called upon; it is the high level of skill, professionalism and caring demeanor that is displayed to citizens calling 911 and to the emergency responders at GCSO and BSFD.

Our staff works 7x24x365 in the support of all public safety services provided by law enforcement, fire, and emergency medical teams throughout Gallatin County. We support and manage all mission critical communications systems to include radio, paging, microwave, and mobile data. Our mission has grown but our budget and staffing has not. Any financial help we can attain to assist us with achieving these goals is immensely beneficial to everyone we serve and in this proposal specifically for the benefit of Big Sky.

Provide the following financial documents:

10) Copy of the entity's complete operating budget for the period 07/01/18 through 06/30/19.

If your fiscal year does not coincide with this time period, please provide complete budgets for the entity's fiscal year that covers the aforementioned time period. For example, if the entity's fiscal year corresponds with a calendar year, provide two budgets 1) 01/01/2018 through 12/31/2018 and 2) 01/01/2019 through 12/31/2019. ATTACHED

11) Organization's Profit and Loss Report, Budget vs. Actual Report and Balance Sheet from your previous completed fiscal year. ATTACHED

12) Organization's Profit and Loss Report, Budget vs. Actual Report and Balance Sheet from your current fiscal year to date. ATTACHED

13) For applicants with mill levy authority please provide the following:
a. A map of your district's boundaries Our district encompasses all of Gallatin County
b. The current taxable value of your district $286,963,193

N/A

c. If applicable, the current mill levy rate

9 mills at 286K

d. **Using the information above, provide a detailed budgetary breakdown of the potential tax burden per $100,000 value, for property owners within your district if mill levy authority would be used to fund this project rather than resort tax funds.**

None, all mill funds are required for 911 operations.

TOTAL ORGANIZATIONAL BUDGET FOR THE YEAR $ 3,908,700

(Include all organization projects and programs, not only those requesting Resort Tax funding. This number should match the organization's Revenue from Profit and Loss Report)

PRINCIPLE	ITEM	AMOUNT	PERCENTAGE
Revenue	Request from Resort Tax	$923,344	0
	Other Public Grants	N/A	0
	Private Donor Contributions (not including In-kind)	N/A	0%
	Fundraising Events	N/A	0%
	Revenue Other*	2,985,356	0
	Sub Total Revenue	2,985,356	100%
	Private Donor Contributions In-kind	N/A	0%
	Total Revenue	3,908,700	100% (the revenue line items above should total)
Expenses	Personnel: 26 # of FTE Paid Personnel 0 # of FTE Contract Personnel Do not include volunteer time (in the amount column include the total expense including salary, benefits and payroll taxes)	1,988,931	0%
	Operations	1,919,769	0%
	Programming	N/A	0%
	Expenses Other**	N/A	0%
Capital Expenditures	Total Capital Expenditures	923,344	0%
	Total Expenses		100% (the expenses line items above should total)
Income	Net Income		0%

***Revenue Other:** 9 MILLS AT 286K

****Expenses Other:** N/A

Clarifications you'd like to provide regarding the information on this page: ATTACHED FY 19 PROJECTED BUDGET. MORE SPECIFIC INFORMATION CAN BE PROVIDED UPON REQUEST.

RESERVES: Capital, Programming and/or Operating	**On Hand Restricted****	N/A
	On Hand Unrestricted**	N/A
	Goal (if currently no reserves)	N/A

****Purpose of Restricted and Unrestricted Capital Reserves:** _____

_____

TOTAL CASH FLOW 3-YEAR REQUIREMENT
(Include all organization projects and programs, not only those requesting Resort Tax funding)

ITEM	This Current Application's Request from Resort Tax	2020	2021	Total Cash Flow 3-Yr Requirement
Personnel: Paid and/or Contract (include salary, benefits and payroll taxes; do not include volunteer time)	$0	$0	$0	$0
Total # of FTE Personnel	26			NA
Operations	$0	$0	$0	$0
Programming	0	0	0	0
Capital Expenditures	923,344	$0	$0	$0
Other*	0	0	0	0
Total	923,344 $0	$0	$0	$0

RESORT TAX REQUEST	923,344 $0	$0	$0	$0

Describe financial increases and decreases and the projects for which resort tax funds may be requested.

2020 N/A

2021 N/A

***Other Description** N/A

Big Sky Communications Upgrade Project Cost Breakdown
For: Gallatin County Sheriff's Office and Big Sky Fire

Backbone (Highway for voice and data)
**Aviat Digital Microwave - Lone Peak to Virginia City Pass
Proposal includes hardware and installation
Path already engineered and verified
Includes all network and alarming devices
Maintenance covered by 911 staff
Installation by: Dunne Communications
Helicopter Sling Load
(Grant proposal that is currently not funded is for $250,000.)

SUBTOTAL: $250,000

Redundancy for Data
Fiber Optic Data Network – Primary path for data/internet communications
To the Big Sky Fire Department and Gallatin County Sheriff's Office Location
Proposal includes integration, hardware and installation
Annual costs to be paid for by Gallatin County 911

SUBTOTAL: $25,536.00

Mission Critical Land Mobile Radio Solution (rides the Aviat Digital Microwave)
Motorola Four (4) GTR 8000, 800 MHz Conventional Repeaters
Rack mounted, high efficiency power units
Includes hardware, antennas, back-up batteries in rack
Maintenance covered by 911 staff
Installation by Industrial Communications and 911 Staff
Battery system (NewMar Solution)
Installation by Industrial Communications and 911 Staff
(Motorola $140K, Power and Installation $27K, $20K
Engineering and Testing)

SUBTOTAL: $187,000

UHF Digital Paging Solution (rides the Aviat Digital Microwave)
RfTechnologies (via Industrial Communications) Paging for Big Sky
System already engineered and ready for purchase.
Designed specifically for Big Sky with MW link on Lone Peak
Includes hardware, installation by Industrial, and maintenance
(HW $23,308, Installation $2500)

SUBTOTAL: $25,808

TOTAL FOR SYSTEM UPGRADES: $488,344

Mobile and Portable Radios - Dual-band VHF/800 MHz w/installation

Big Sky Fire

Portables - 25-APX 8000
Mobiles - 18 -APX 7500HP

SUBTOTAL: $ 300,000.00

Gallatin County Sheriff's Office

Portables - 8 APX 8000
Mobiles - 16 APX 7500HP (This quantity covers deputies assigned to Big Sky and those used for special events in the Big Sky area.)

SUBTOTAL: $150,000

TOTAL FOR RADIO UPGRADES: $450,000

FY2019 Start Up Expenditures

GALLATIN COUNTY

FY19

2300 PUBLIC SAFETY FUND
250 DISPATCH SERVICES

Account Number		2017 ACTUALS	2018 BUDGET	2018 ESTIM YR END	2019 START-UP	2019 DEPT. REQUEST
42	PUBLIC SAFETY					
42-07	OTHER EMERGENCY SERVICES					
42-07-50	CENTRAL EMERGENCY DISPATCH					
42-07-50-100	PERSONNEL SERVICES					
42-07-50-110	SALARIES AND WAGES - PERMANENT	1,047,884	1,300,115	1,116,711	1,402,912	[ ]
42-07-50-112	SALARIES AND WAGES - TEMPORARY	4,976	23,714	1,132	23,714	[ ]
42-07-50-120	OVERTIME - PERMANENT JOINT DISP.	140,073	40,000	230,973	40,000	[ ]
42-07-50-140	EMPLOYER CONTRIBUTIONS JOINT DI	383,100	493,699	430,449	517,206	[ ]
42-07-50-141	W. C. EMPLOYER CONTRIBUTIONS	5,468	4,835	5,485	5,099	[ ]
Total	PERSONNEL SERVICES	1,581,501	1,862,363	1,784,750	1,988,931	
42-07-50-200	SUPPLIES					
42-07-50-205	SUPPLIES	0	0	0	7,000	[ ]
42-07-50-210	OFFICE SUPPLIES JOINT DISP.	5,685	5,000	6,719	0	[ ]
42-07-50-215	TOOLS AND EQUIPMENT	0	0	1,362	0	[ ]
42-07-50-220	OPERATING SUPPLIES JOINT DISP.	1,442	4,000	6,086	4,000	[ ]
42-07-50-221	SOFTWARE JOINT DISP.	3,774	2,000	9,063	0	[ ]
42-07-50-224	FOOD JOINT DISP.	232	200	375	200	[ ]
42-07-50-227	WEAPONS	0	0	0	0	[ ]
42-07-50-230	REPAIR & MAINTENANCE SUPPLIES JC	12,945	8,300	10,751	9,300	[ ]
42-07-50-231	GAS, OIL. FUEL, GREASE JOINT DISP.	2,369	5,000	1,152	5,000	[ ]
42-07-50-232	TIRES JOINT DISP.	0	1,000	0	0	[ ]
42-07-50-235	EQUIPMENT (NOT OUTLAY) JOINT DISF	1,657-	3,000	14,713	3,000	[ ]
42-07-50-236	COMPUTER AND ITS HARDWARE	6,561	3,000	3,990	3,000	[ ]

2300 PUBLIC SAFETY FUND
250 DISPATCH SERVICES

Account Number		2017 ACTUALS	2018 BUDGET	2018 ESTIM YR END	2019 START-UP	2019 DEPT. REQUEST
Total	SUPPLIES	31,351	31,500	54,211	31,500	
42-07-50-300	PURCHASED SERVICES					
42-07-50-312	POSTAGE JOINT DISP.	853	825	987	825	[ ]
42-07-50-315	INTERNET SERVICES	731	750	1,079	0	[ ]
42-07-50-320	PRINTING AND DUPLICATING JOINT DI	395	350	713	350	[ ]
42-07-50-330	SUBSCRIPTIONS & DUES JOINT DISP.	119	150	227	3,650	[ ]
42-07-50-331	PUBLCTNS OF FORMAL LEGAL NOTIC	53	100	0	0	[ ]
42-07-50-335	MEMBERSHIP DUES JOINT DISP.	1,183	1,400	1,542	0	[ ]
42-07-50-337	ADVERTISING JOINT DISP.	1,941	2,000	2,936	0	[ ]
42-07-50-340	UTILITIES JOINT DISP.	1,152	1,000	1,186	1,000	[ ]
42-07-50-341	ELECTRIC UTILITIES JOINT DISP.	15,409	17,000	16,240	17,000	[ ]
42-07-50-344	GAS UTILITIES JOINT DISP.	513	1,000	632	1,000	[ ]
42-07-50-345	TELEPHONE JOINT DISP.	46,930	40,000	52,151	45,157	[ ]
42-07-50-346	CELL PHONES JOINT DISP.	5,058	4,640	5,473	0	[ ]
42-07-50-350	PROFESSIONAL SERVICES JOINT DISF	139,055	123,833	134,741	234,405	[ ]
42-07-50-351	MEDICAL SERVICES, VET SERVICES J	0	0	0	0	[ ]
42-07-50-352	LEGAL SERVICES	0	1,700	564	1,700	[ ]
42-07-50-360	REPAIR AND MAINTENANCE JOINT DIS	6,157	1,500	1,907	51,500	[ ]
42-07-50-361	AUTOMOTIVE REPAIRS & MAINT. JOIN	64	2,500	441	2,500	[ ]
42-07-50-362	OFFICE EQUIP. REPAIR & MAINT. JOIN	40,384	50,000	67,403	0	[ ]
42-07-50-363	RADIO - REPAIRS & MAINT. JOINT DISF	76,292	117,757	124,826	117,757	[ ]
42-07-50-366	BUILDING MAINTENANCE ALLOCATED	0	0	0	0	[ ]
42-07-50-370	TRAVEL JOINT DISP.	7,418	6,000	7,518	6,000	[ ]
42-07-50-380	TRAINING JOINT DISP.	12,155	8,900	10,952	8,900	[ ]
42-07-50-390	OTHER PURCHASED SERVICES JOINT	13,371	2,000	0	2,000	[ ]

2300 PUBLIC SAFETY FUND
250 DISPATCH SERVICES

Account Number		2017 ACTUALS	2018 BUDGET	2018 ESTIM YR END	2019 START-UP	2019 DEPT. REQUEST
Total	PURCHASED SERVICES	369,233	383,405	431,518	493,744	
42-07-50-500	FIXED CHARGES					
42-07-50-513	LIABILITY INS - ALLOCATED JOINT DISI	15,529	12,497	15,175	14,981	[ ]
42-07-50-530	RENT JOINT DISP.	1,841	5,200	4,775	5,200	[ ]
42-07-50-540	SPECIAL ASSESSMENTS	7	0	8	0	[ ]
42-07-50-570	LICENSES	0	0	142	0	[ ]
Total	FIXED CHARGES	17,377	17,697	20,100	20,181	
42-07-50-600	DEBT SERVICE					
42-07-50-610	PRINCIPAL	108,081	102,731	69,964	0	[ ]
42-07-50-620	INTEREST JOINT DISP.	4,854	5,019	869	0	[ ]
42-07-50-630	SERVICE CHARGES JOINT DISP.	105	0	89	0	[ ]
Total	DEBT SERVICE	113,040	107,750	70,922	0	
42-07-50-800	OTHER OBJECTS					
42-07-50-820	TRANSFER TO OTHER FUNDS	4,418	0	0	0	[ ]
42-07-50-890	PUBLIC EDUCATION JOINT DISP.	0	1,000	0	1,000	[ ]
Total	OTHER OBJECTS	4,418	1,000	0	1,000	
42-07-50-900	CAPITAL OUTLAY					
42-07-50-905	CAPITAL RESERVES	0	0	0	0	[ ]
42-07-50-910	LAND OUTLAY JOINT DISP.	0	0	0	0	[ ]
42-07-50-915	SOFTWARE	0	0	0	0	[ ]
42-07-50-920	BUILDINGS JOINT DISP.	0	0	0	0	[ ]
42-07-50-940	MACHINERY & EQUIPMENT JOINT DISF	1,602,719	330,000	97,377	450,000	[ ]

2300 PUBLIC SAFETY FUND
250 DISPATCH SERVICES

Account Number		2017 ACTUALS	2018 BUDGET	2018 ESTIM YR END	2019 START-UP	2019 DEPT. REQUEST
Total	CAPITAL OUTLAY	1,602,719	330,000	97,377	450,000	
Total	CENTRAL EMERGENCY DISPATCH	3,719,639	2,733,715	2,458,878	2,985,356	
Total	OTHER EMERGENCY SERVICES	3,719,639	2,733,715	2,458,878	2,985,356	
Total	DISPATCH SERVICES	3,719,639	2,733,715	2,458,878	2,985,356	
Total	PUBLIC SAFETY FUND	3,719,639	2,733,715	2,458,878	2,985,356	
	Grand Total	3,719,639	2,733,715	2,458,878	2,985,356	

Expenditure Status Report

GALLATIN COUNTY
7/1/2017 through 4/30/2018 FY18 Current

2300 PUBLIC SAFETY FUND

250 DISPATCH SERVICES

Account Number		Adjusted Appropriation	Expenditures	Year-to-date Expenditures	Year-to-date Encumbrances	Balance	Prct Used
42	PUBLIC SAFETY						
42-07	OTHER EMERGENCY SERVICES						
42-07-50	CENTRAL EMERGENCY DISPATCH						
42-07-50-100	PERSONNEL SERVICES						
42-07-50-110	SALARIES AND WAGES - PERMANENT JOINT DIS	1,300,115.00	884,062.50	884,062.50	0.00	416,052.50	68.00
42-07-50-112	SALARIES AND WAGES - TEMPORARY	23,714.00	896.51	896.51	0.00	22,817.49	3.78
42-07-50-120	OVERTIME - PERMANENT JOINT DISP.	40,000.00	182,853.46	182,853.46	0.00	-142,853.46	457.13
42-07-50-140	EMPLOYER CONTRIBUTIONS JOINT DISP.	493,699.00	340,771.95	340,771.95	0.00	152,927.05	69.02
42-07-50-141	W. C. EMPLOYER CONTRIBUTIONS	4,835.00	4,342.56	4,342.56	0.00	492.44	89.82
	Total PERSONNEL SERVICES	1,862,363.00	1,412,926.98	1,412,926.98	0.00	449,436.02	75.87
42-07-50-200	SUPPLIES						
42-07-50-210	OFFICE SUPPLIES JOINT DISP.	5,000.00	5,319.06	5,319.06	0.00	-319.06	106.38
42-07-50-215	TOOLS AND EQUIPMENT	0.00	1,078.00	1,078.00	0.00	-1,078.00	0.00
42-07-50-220	OPERATING SUPPLIES JOINT DISP.	4,000.00	4,818.37	4,818.37	0.00	-818.37	120.46
42-07-50-221	SOFTWARE JOINT DISP.	2,000.00	7,174.55	7,174.55	0.00	-5,174.55	358.73
42-07-50-224	FOOD JOINT DISP.	200.00	296.89	296.89	0.00	-96.89	148.45
42-07-50-227	WEAPONS	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-230	REPAIR & MAINTENANCE SUPPLIES JOINT DISP	8,300.00	8,511.00	8,511.00	0.00	-211.00	102.54
42-07-50-231	GAS, OIL. FUEL, GREASE JOINT DISP.	5,000.00	912.22	912.22	0.00	4,087.78	18.24
42-07-50-232	TIRES JOINT DISP.	1,000.00	0.00	0.00	0.00	1,000.00	0.00
42-07-50-235	EQUIPMENT (NOT OUTLAY) JOINT DISP.	3,000.00	11,647.64	11,647.64	0.00	-8,647.64	388.25
42-07-50-236	COMPUTER AND ITS HARDWARE	3,000.00	3,158.56	3,158.56	0.00	-158.56	105.29
	Total SUPPLIES	31,500.00	42,916.29	42,916.29	0.00	-11,416.29	136.24
42-07-50-300	PURCHASED SERVICES						
42-07-50-312	POSTAGE JOINT DISP.	825.00	781.33	781.33	0.00	43.67	94.71

Expenditure Status Report

GALLATIN COUNTY
7/1/2017 through 4/30/2018

2300 PUBLIC SAFETY FUND

250 DISPATCH SERVICES

Account Number		Adjusted Appropriation	Expenditures	Year-to-date Expenditures	Year-to-date Encumbrances	Balance	Prct Used
42-07-50-315	INTERNET SERVICES	750.00	854.18	854.18	0.00	-104.18	113.89
42-07-50-320	PRINTING AND DUPLICATING JOINT DISP.	350.00	564.53	564.53	0.00	-214.53	161.29
42-07-50-330	SUBSCRIPTIONS & DUES JOINT DISP.	150.00	179.40	179.40	0.00	-29.40	119.60
42-07-50-331	PUBLCTNS OF FORMAL LEGAL NOTIC	100.00	0.00	0.00	0.00	100.00	0.00
42-07-50-335	MEMBERSHIP DUES JOINT DISP.	1,400.00	1,221.00	1,221.00	0.00	179.00	87.21
42-07-50-337	ADVERTISING JOINT DISP.	2,000.00	2,324.40	2,324.40	0.00	-324.40	116.22
42-07-50-340	UTILITIES JOINT DISP.	1,000.00	938.97	938.97	0.00	61.03	93.90
42-07-50-341	ELECTRIC UTILITIES JOINT DISP.	17,000.00	12,856.60	12,856.60	0.00	4,143.40	75.63
42-07-50-344	GAS UTILITIES JOINT DISP.	1,000.00	500.45	500.45	0.00	499.55	50.05
42-07-50-345	TELEPHONE JOINT DISP.	40,000.00	41,286.14	41,286.14	0.00	-1,286.14	103.22
42-07-50-346	CELL PHONES JOINT DISP.	4,640.00	4,332.98	4,332.98	0.00	307.02	93.38
42-07-50-350	PROFESSIONAL SERVICES JOINT DISP.	123,833.00	106,669.71	106,669.71	0.00	17,163.29	86.14
42-07-50-351	MEDICAL SERVICES, VET SERVICES JOINT DIS	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-352	LEGAL SERVICES	1,700.00	446.50	446.50	0.00	1,253.50	26.26
42-07-50-360	REPAIR AND MAINTENANCE JOINT DISP.	1,500.00	1,510.00	1,510.00	0.00	-10.00	100.67
42-07-50-361	AUTOMOTIVE REPAIRS & MAINT. JOINT DISP.	2,500.00	349.00	349.00	0.00	2,151.00	13.96
42-07-50-362	OFFICE EQUIP. REPAIR & MAINT. JOINT DISP	50,000.00	53,360.54	53,360.54	0.00	-3,360.54	106.72
42-07-50-363	RADIO - REPAIRS & MAINT. JOINT DISP.	117,757.00	98,820.33	98,820.33	0.00	18,936.67	83.92
42-07-50-366	BUILDING MAINTENANCE ALLOCATED JOINT DIS	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-370	TRAVEL JOINT DISP.	6,000.00	5,951.32	5,951.32	0.00	48.68	99.19
42-07-50-380	TRAINING JOINT DISP.	8,900.00	8,670.41	8,670.41	0.00	229.59	97.42
42-07-50-390	OTHER PURCHASED SERVICES JOINT DISP.	2,000.00	0.00	0.00	0.00	2,000.00	0.00
	Total PURCHASED SERVICES	383,405.00	341,617.79	341,617.79	0.00	41,787.21	89.10
42-07-50-500	FIXED CHARGES						
42-07-50-513	LIABILITY INS - ALLOCATED JOINT DISP.	12,497.00	12,013.17	12,013.17	0.00	483.83	96.13
42-07-50-530	RENT JOINT DISP.	5,200.00	3,780.00	3,780.00	0.00	1,420.00	72.69
42-07-50-540	SPECIAL ASSESSMENTS	0.00	6.60	6.60	0.00	-6.60	0.00
42-07-50-570	LICENSES	0.00	112.00	112.00	0.00	-112.00	0.00
	Total FIXED CHARGES	17,697.00	15,911.77	15,911.77	0.00	1,785.23	89.91
42-07-50-600	DEBT SERVICE						

Expenditure Status Report

GALLATIN COUNTY
7/1/2017 through 4/30/2018

2300 PUBLIC SAFETY FUND

250 DISPATCH SERVICES

Account Number		Adjusted Appropriation	Expenditures	Year-to-date Expenditures	Year-to-date Encumbrances	Balance	Prct Used
42-07-50-610	PRINCIPAL	102,731.00	55,388.39	55,388.39	0.00	47,342.61	53.92
42-07-50-620	INTEREST JOINT DISP.	5,019.00	688.00	688.00	0.00	4,331.00	13.71
42-07-50-630	SERVICE CHARGES JOINT DISP.	0.00	70.07	70.07	0.00	-70.07	0.00
	Total DEBT SERVICE	107,750.00	56,146.46	56,146.46	0.00	51,603.54	52.11
42-07-50-800	OTHER OBJECTS						
42-07-50-820	TRANSFER TO OTHER FUNDS	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-890	PUBLIC EDUCATION JOINT DISP.	1,000.00	0.00	0.00	0.00	1,000.00	0.00
	Total OTHER OBJECTS	1,000.00	0.00	0.00	0.00	1,000.00	0.00
42-07-50-900	CAPITAL OUTLAY						
42-07-50-905	CAPITAL RESERVES	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-910	LAND OUTLAY JOINT DISP.	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-915	SOFTWARE	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-920	BUILDINGS JOINT DISP.	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-940	MACHINERY & EQUIPMENT JOINT DISP.	330,000.00	77,090.23	77,090.23	0.00	252,909.77	23.36
	Total CAPITAL OUTLAY	330,000.00	77,090.23	77,090.23	0.00	252,909.77	23.36
	Total PUBLIC SAFETY FUND	2,733,715.00	1,946,609.52	1,946,609.52	0.00	787,105.48	71.21
	Grand Total	2,733,715.00	1,946,609.52	1,946,609.52	0.00	787,105.48	71.21

Expenditure Status Report

GALLATIN COUNTY
7/1/2016 through 6/30/2017 FY17

2300 PUBLIC SAFETY FUND

250 DISPATCH SERVICES

Account Number		Adjusted Appropriation	Expenditures	Year-to-date Expenditures	Year-to-date Encumbrances	Balance	Prct Used
42	PUBLIC SAFETY						
42-07	OTHER EMERGENCY SERVICES						
42-07-50	CENTRAL EMERGENCY DISPATCH						
42-07-50-100	PERSONNEL SERVICES						
42-07-50-110	SALARIES AND WAGES - PERMANENT JOINT DIS	1,271,765.00	1,047,884.39	1,047,884.39	0.00	223,880.61	82.40
42-07-50-112	SALARIES AND WAGES - TEMPORARY	23,714.00	4,975.72	4,975.72	0.00	18,738.28	20.98
42-07-50-120	OVERTIME - PERMANENT JOINT DISP.	40,000.00	140,073.20	140,073.20	0.00	-100,073.20	350.18
42-07-50-140	EMPLOYER CONTRIBUTIONS JOINT DISP.	465,241.00	383,099.83	383,099.83	0.00	82,141.17	82.34
42-07-50-141	W. C. EMPLOYER CONTRIBUTIONS	6,401.00	5,467.76	5,467.76	0.00	933.24	85.42
	Total PERSONNEL SERVICES	1,807,121.00	1,581,500.90	1,581,500.90	0.00	225,620.10	87.51
42-07-50-200	SUPPLIES						
42-07-50-210	OFFICE SUPPLIES JOINT DISP.	5,000.00	5,685.40	5,685.40	0.00	-685.40	113.71
42-07-50-215	TOOLS AND EQUIPMENT	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-220	OPERATING SUPPLIES JOINT DISP.	4,000.00	1,442.05	1,442.05	0.00	2,557.95	36.05
42-07-50-221	SOFTWARE JOINT DISP.	2,000.00	3,773.70	3,773.70	0.00	-1,773.70	188.69
42-07-50-224	FOOD JOINT DISP.	250.00	231.80	231.80	0.00	18.20	92.72
42-07-50-227	WEAPONS	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-230	REPAIR & MAINTENANCE SUPPLIES JOINT DISP	8,300.00	12,945.18	12,945.18	0.00	-4,645.18	155.97
42-07-50-231	GAS, OIL. FUEL, GREASE JOINT DISP.	5,000.00	2,368.56	2,368.56	0.00	2,631.44	47.37
42-07-50-232	TIRES JOINT DISP.	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-235	EQUIPMENT (NOT OUTLAY) JOINT DISP.	3,000.00	-1,657.37	-1,657.37	0.00	4,657.37	55.25
42-07-50-236	COMPUTER AND ITS HARDWARE	3,000.00	6,560.65	6,560.65	0.00	-3,560.65	218.69
	Total SUPPLIES	30,550.00	31,349.97	31,349.97	0.00	-799.97	102.62
42-07-50-300	PURCHASED SERVICES						
42-07-50-312	POSTAGE JOINT DISP.	825.00	852.70	852.70	0.00	-27.70	103.36

Expenditure Status Report

GALLATIN COUNTY
7/1/2016 through 6/30/2017

2300 PUBLIC SAFETY FUND

250 DISPATCH SERVICES

Account Number		Adjusted Appropriation	Expenditures	Year-to-date Expenditures	Year-to-date Encumbrances	Balance	Prct Used
42-07-50-315	INTERNET SERVICES	0.00	731.42	731.42	0.00	-731.42	0.00
42-07-50-320	PRINTING AND DUPLICATING JOINT DISP.	350.00	394.81	394.81	0.00	-44.81	112.80
42-07-50-330	SUBSCRIPTIONS & DUES JOINT DISP.	150.00	119.40	119.40	0.00	30.60	79.60
42-07-50-331	PUBLCTNS OF FORMAL LEGAL NOTIC	0.00	53.00	53.00	0.00	-53.00	0.00
42-07-50-335	MEMBERSHIP DUES JOINT DISP.	1,400.00	1,183.00	1,183.00	0.00	217.00	84.50
42-07-50-337	ADVERTISING JOINT DISP.	2,000.00	1,940.55	1,940.55	0.00	59.45	97.03
42-07-50-340	UTILITIES JOINT DISP.	1,000.00	1,151.75	1,151.75	0.00	-151.75	115.18
42-07-50-341	ELECTRIC UTILITIES JOINT DISP.	17,000.00	15,409.30	15,409.30	0.00	1,590.70	90.64
42-07-50-344	GAS UTILITIES JOINT DISP.	1,000.00	512.83	512.83	0.00	487.17	51.28
42-07-50-345	TELEPHONE JOINT DISP.	32,049.00	46,929.81	46,929.81	0.00	-14,880.81	146.43
42-07-50-346	CELL PHONES JOINT DISP.	4,640.00	5,057.63	5,057.63	0.00	-417.63	109.00
42-07-50-350	PROFESSIONAL SERVICES JOINT DISP.	110,695.00	139,055.36	139,055.36	0.00	-28,360.36	125.62
42-07-50-351	MEDICAL SERVICES, VET SERVICES JOINT DIS	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-352	LEGAL SERVICES	1,700.00	0.00	0.00	0.00	1,700.00	0.00
42-07-50-360	REPAIR AND MAINTENANCE JOINT DISP.	2,000.00	6,156.89	6,156.89	0.00	-4,156.89	307.84
42-07-50-361	AUTOMOTIVE REPAIRS & MAINT. JOINT DISP.	2,500.00	63.75	63.75	0.00	2,436.25	2.55
42-07-50-362	OFFICE EQUIP. REPAIR & MAINT. JOINT DISP	57,650.00	40,383.74	40,383.74	0.00	17,266.26	70.05
42-07-50-363	RADIO - REPAIRS & MAINT. JOINT DISP.	117,757.00	76,292.38	76,292.38	0.00	41,464.62	64.79
42-07-50-366	BUILDING MAINTENANCE ALLOCATED JOINT DIS	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-370	TRAVEL JOINT DISP.	6,000.00	7,418.39	7,418.39	0.00	-1,418.39	123.64
42-07-50-380	TRAINING JOINT DISP.	8,900.00	12,154.92	12,154.92	0.00	-3,254.92	136.57
42-07-50-390	OTHER PURCHASED SERVICES JOINT DISP.	6,525.00	13,370.77	13,370.77	0.00	-6,845.77	204.92
	Total PURCHASED SERVICES	374,141.00	369,232.40	369,232.40	0.00	4,908.60	98.69
42-07-50-500	FIXED CHARGES						
42-07-50-513	LIABILITY INS - ALLOCATED JOINT DISP.	16,545.00	15,529.00	15,529.00	0.00	1,016.00	93.86
42-07-50-530	RENT JOINT DISP.	5,200.00	1,840.80	1,840.80	0.00	3,359.20	35.40
42-07-50-540	SPECIAL ASSESSMENTS	0.00	6.60	6.60	0.00	-6.60	0.00
42-07-50-570	LICENSES	0.00	0.00	0.00	0.00	0.00	0.00
	Total FIXED CHARGES	21,745.00	17,376.40	17,376.40	0.00	4,368.60	79.91
42-07-50-600	DEBT SERVICE						

Expenditure Status Report

GALLATIN COUNTY
7/1/2016 through 6/30/2017

2300 PUBLIC SAFETY FUND

250 DISPATCH SERVICES

Account Number		Adjusted Appropriation	Expenditures	Year-to-date Expenditures	Year-to-date Encumbrances	Balance	Prct Used
42-07-50-610	PRINCIPAL	102,731.00	108,081.14	108,081.14	0.00	-5,350.14	105.21
42-07-50-620	INTEREST JOINT DISP.	5,019.00	4,854.05	4,854.05	0.00	164.95	96.71
42-07-50-630	SERVICE CHARGES JOINT DISP.	0.00	105.01	105.01	0.00	-105.01	0.00
	Total DEBT SERVICE	107,750.00	113,040.20	113,040.20	0.00	-5,290.20	104.91
42-07-50-800	OTHER OBJECTS						
42-07-50-820	TRANSFER TO OTHER FUNDS	0.00	4,417.95	4,417.95	0.00	-4,417.95	0.00
42-07-50-890	PUBLIC EDUCATION JOINT DISP.	1,000.00	0.00	0.00	0.00	1,000.00	0.00
	Total OTHER OBJECTS	1,000.00	4,417.95	4,417.95	0.00	-3,417.95	441.80
42-07-50-900	CAPITAL OUTLAY						
42-07-50-910	LAND OUTLAY JOINT DISP.	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-915	SOFTWARE	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-920	BUILDINGS JOINT DISP.	0.00	0.00	0.00	0.00	0.00	0.00
42-07-50-940	MACHINERY & EQUIPMENT JOINT DISP.	195,578.00	1,602,718.76	1,602,718.76	0.00	-1,407,140.76	819.48
	Total CAPITAL OUTLAY	195,578.00	1,602,718.76	1,602,718.76	0.00	-1,407,140.76	819.48
	Total PUBLIC SAFETY FUND	2,537,885.00	3,719,636.58	3,719,636.58	0.00	-1,181,751.58	146.56
	Grand Total	2,537,885.00	3,719,636.58	3,719,636.58	0.00	-1,181,751.58	146.56

MissionCriticalPartners
Because the Mission Matters

Status Report

Final Report

PREPARED MAY 3, 2017
FOR GALLATIN COUNTY, MONTANA

MissionCriticalPartners.com
Dallas Office | 502 N. Carroll Ave. Suite 120 | Southlake, TX 76092 | 888.8.MCP.911 or 888.862.7911

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Executive Summary

Mission Critical Partners, Inc. (MCP) has been working with Gallatin County (County) for three months to assess public safety radio communications in the county. Currently, first responders in the county operate on very-high frequency (VHF) conventional and the state's VHF trunking systems, and plans exist to add 800 megahertz (MHz) trunking capability. MCP personnel reviewed the previous consultant's report[1] and Motorola service records, participated in the Motorola 800 MHz customer design review, and visited the Nixon, Law and Justice, E-911, and Kenyon Water Tank antenna sites.

The single most significant observation made from a radio communications perspective concerns the effect population growth in the Cities of Bozeman and Belgrade as well as the Four Corners area is having on public safety communications in the county. These areas have experienced higher than normal growth over the past several years, which is expected to continue.[2] The Sanderson Stewart Planning Study makes several recommendations regarding civil infrastructure planning designed to manage the effects of this growth, for fiscal responsibility and public health reasons.

The entire State of Montana has elected to use the VHF radio band, because VHF signals propagate arounds hills and mountains, and travel farther than the other bands typically used for public safety communications. For most of the state, the VHF band has been the right application. However, in areas of any significant population—such as that found in Gallatin County—the dominant band changes from VHF and UHF to the urban-friendly 700/800 MHz.

In the past, public safety communications problems in Gallatin County have been addressed in the context of a rural environment, a strategy that has exacerbated problems instead of mitigating them. Going forward, the same planning and policy considerations applied to water and electricity in the county need to be applied to the radio infrastructure. That planning starts with realizing that this area, due to its extensive growth, needs to be treated as an urban environment, rather than rural, as it relates to public safety communications.

Communications around the Bozeman, Belgrade and the Four Corners area have been based on VHF conventional technology, which is well suited for rural areas. As communications gaps in this urban area were identified, additional repeaters were added to the system. In addition, several unproven solutions were implemented to achieve wide-area communications. However, none of these tactics address the overarching problem, which is the population growth in the rural areas. The County should develop a forward-looking communications plan that incorporates an urban component that takes into account projected population growth.

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[1] *9-1-1 Radio System Engineering Study*, ADCOMM Engineering Study, September 8, 2015
[2] *Gallatin Triangle Planning Study*, Sanderson Stewart, September 17, 2017

The following factors currently are hindering communications in Gallatin County:

- The VHF band inherently experiences desense and degradation of receiver sensitivity—which generally is caused by radio noise generated by multiple users nearby
- The noise floor is increased in urban areas
- Unproven technology causing unpredictable communications
- Intermodulation
- Using rural solutions in urban areas of the county

The addition of the 800 MHz trunking site is only the first step in a radio infrastructure plan that addresses the public safety communications issues being experienced in the county in what has become an urban radio frequency (RF) environment. This document will address the problems and recommend solutions for Gallatin County. Ultimately, the County will need to adopt a hybrid VHF (rural) and 800 MHz (urban) communications plan.

1 RF Recommendations for Law North and Law West

As part of the consulting and engineering review of the County's public safety communications migration and upgrade plan, MCP visited various radio sites in the county. The purpose of these visits was to identify the root cause of user complaints. Users complained of dropped calls, static during the calls, and a general sense of unreliability concerning radio communications. These problems occur frequently and there is a procedure for requesting a backup channel.

The following sites were visited:

- Nixon – Existing VHF conventional and VHF trunking site
- Law and Justice – Existing VHF conventional fill site
- E-911 – Area PSAP – VHF Conventional Sites
- Kenyon Water Tank – VHF Conventional, VHF trunking and planned 800 MHz trunking site

The following systems were observed:

- Steered[3] Fire North VHF repeater system
- Sloppy Cast[4] VHF Law North repeater system
- Law and Justice North site being used as a distributed antenna system (DAS) for the Law North VHF channel
- Existing State of Montana VHF trunking sites
- The new 800 MHz trunking site for urban coverage

Several issues exist related to user reports of unreliability and poor reception concerning the VHF radios. The following describes the contributing factors.

1.1 Unreliability Due to Single Points of Failure and Insufficient Back Up Power

A previous consultant was hired to observe, among many issues, single points of failure and insufficient backup power on the VHF conventional channels. The power conclusions from the ADCOMM report still hold true and can be referenced. Upon arrival at the Nixon site, it was observed that a power failure had occurred; as a result, multiple channels required technical support to restore their operation.

Although the site had backup power, it was the first generation of Eltek equipment and the company no longer sells these power cards. Repairs are limited to a few components of the card. If the component cannot be repaired, it is discarded. All sites have this version of power supply. There are too few spares in

[3] To give Fire North wide-area communications, a steering mechanism was added to a central site and remote boxes were installed at the remote sites. The resultant effect is that only one transmitter will be in operation at any given time. —Consequently, users will miss conversations due to this configuration.
[4] A manual voting system has been added into the network. More-robust simulcast equipment exists to provide more-efficient simulcast. Users will experience static and poor coverage with the current design.

the system to support a public safety communications system with any reliability. There are several other examples of these kinds of issues in the original consultant's report.

1.2 Interference Caused by Desense

There was a complaint of intermittent radio communications at the Law and Justice site. A quick demonstration showed that two radios in the same room could cause a radio desense situation. Desense occurs when one radio is transmitting and another receiving radio in close proximity cannot filter the desired frequency from the transmitting frequency. Hence, radios receiving the same frequency or other frequencies near the transmitting radio may not provide clear communications to the user.

VHF and UHF systems both experience this issue. Because the radio can transmit at any frequency it can receive, this is a common issue. Several officers in the same room performing a radio test observed this issue and attributed it to a failure of the channel. For most urban public safety communications systems, having many units that are in close proximity can cause this issue.

1.3 Interference Caused by Intermodulation

After performing intermodulation calculations on the County's frequencies, there are two combinations of frequencies that allow for this potential interference. See Table 1 below. This phenomenon is a real factor that plagues the VHF spectrum, though it is forgiving in rural environments because a manmade source is needed to mix the signals.

Table 1: Frequency Combinations Causing Third-Order Intermodulation

Radio 1	Radio 2	Radio 3	Channel Degraded
Law North	County Fire East	Fire West	Fire North Dispatch
Law North	Fire Central	Fire West	Bozeman Fire

When these three VHF frequency combinations are keyed up near each other, third-order intermodulation is produced. In urban environments, intermodulation presents itself more frequently, as there are several manmade sources to fuel the intermodulation. For example, intermodulation occurs at the intersections of two dissimilar metals. In an urban environment, there are literally hundreds of potential sources in a single building. This phenomenon does not exist in the 700 MHz or 800 MHz band.

1.4 Degraded Noise Floor

Measurements were performed in April 2017 at five VHF RF sites. These results show a 20 decibel (dB) to 27 dB loss of signal at the various sites. Every 3 dB is equal to half the signal level. This is equivalent to halving the power 7 to 9 times for each of the sites. These results have been measured for years in the county. The first record of this degradation occurred five years after a Motorola Technologist visited the High Flats site in 2012, and again, in 2015, by the *Radio System Engineering Study* provided by ADCOMM to the County.

1.5 Performance Degraded by Unproven Technology

Law North and Fire North have unproven technology cores. At the time of deployment, the “steered” Fire North solution and the Law North “Sloppy Cast” solutions helped the County move toward a marginal improvement of coverage and increased reliability at a fraction of the commercial costs. Now that this technology is more cost effective, the County needs to source reliable, proven commercial off-the-shelf (COTS) simulcast solutions.

1.6 Change Antenna Configuration

The Law and Justice site is operating as a DAS. This site needs to be incorporated into the system as a wide-area site. Doing this, along with Bozeman Police Department’s use of the 800 MHz trunking site, will improve communications in the area served by the Law and Justice site.

1.7 Findings

Interference: Desense, Intermodulation, and Noise Floor
There are hundreds of users in near proximity to each other that create desense, intermodulation, and an increased noise floor. When a dispatch call occurs that brings more first responders to the emergency scene, these interference issues exacerbate. In the past, the solution was to implement another repeater in the area.

Solution:
The interference issues described above are prevalent in the VHF and UHF frequency bands. These issues become exacerbated in urban locations. Many state plans (Texas and Missouri, for instance) use VHF systems in rural areas and 800 MHz or 700 MHz systems in urban areas. While this would require public safety users working in both environments to carry an extra radio or radios capable of receiving both frequencies, the County should adopt this approach for its communications going forward.

By off-loading the urban traffic to the 800 MHz system, the problems concerning interference and noise floor will improve marginally. Users might notice improved reliability or consistency in the VHF band. However, there still are commercial users and other VHF users that will be present and will continue to cause the issues described above.

Unproven Technology
During the life of the Law North and Steered Fire North systems, unproven technology was used to expand coverage and attempt to mitigate the interference. Although these solutions served their purpose at the time, these devices do not allow for consistent or reliable communications.

Solution:
Simulcast and multicast voting technology has reduced dramatically in price. Proven solutions need to be implemented for trusted, reliable, and consistent public safety solutions. The County should utilize proven COTS technology and should consider upgrading both systems to simulcast solutions.

2 Engineering Support for the 800 MHz Trunking System

2.1 Planning and Status for the 800 MHz Radio Site

2.1.1 Procurement of the Subscriber Radios

The City of Bozeman and other urban users are starting to procure subscriber radios that are properly equipped to operate in the VHF and 800 MHz bands. Because this is new technology, it is recommended that you confer with your vendor or another expert before configuring your radio on the new system.

2.1.2 Status of the Implementation

Progress on the implementation of the 800 MHz system continues. The next steps in the implementation involve upgrading microwave radio sites and installing the RF antenna system at Kenyon Water Tank. Cutover is scheduled for the third quarter of 2017.

2.1.3 User Experience at 800 MHz

The user experience for any city and county radio operating in the 800 MHz band will be much different than what is experienced by users today. Groups of people in the same room cannot desense themselves. The channels that showed intermodulation degradation in the VHF band will not experience it in the 800 MHz band with the proper selection of frequencies. Moreover, once the system is optimized, the trunking system will provide a far more consistent experience for the users.

Because it is expected that the County will benefit from the new 800 MHz radio system, County departments that operate primarily in the range of the that system should consider buying dual-band radios. Although all the channels will be interoperable, current County radios will be accessing the system via the VHF channels. Interoperability is still achieved, but VHF users still may experience the adverse effects mentioned in Section 1.

3 Provide RF Consulting and Engineering for Future Migration

3.1 Recommendations

3.1.1 Grow the 800 MHz Coverage

The County should start planning now for expanding the system to keep up with population growth, particularly in the Bozeman, Belgrade, and Four Corners areas. Although Bozeman proper has coverage, it needs to be expanded to include Belgrade and the Four Corners. Several Law North repeaters cover this area now. Initial coverage maps from Motorola demonstrate two more sites would cover these areas.

These sites also will help with in-building coverage. Whereas VHF signals curve around mountains and other terrain, they do not penetrate buildings as effectively as 800 MHz signals. Rural coverage usually is

designed to extend as far from the antenna site as possible. In contrast, urban coverage is to ensure that the signal can penetrate heavy buildings and potentially basements.

3.1.2 VHF

Most of this document is focused on the urban areas and the 800 MHz band, because that is where most of the County's public safety radio communications problems exist. Operating in the VHF band in urban areas results in the issues described in Section 1. However, the VHF band always must be part of the County's radio system planning, because there are rural areas where the VHF band is the only viable solution.

The current VHF platforms currently used by the County organizations require financial support and a design overhaul to make them effective. Coverage is inconsistent and there also are single points of failure and a lack of backup power. In addition, some sites may need to be reconsidered as viable VHF sites once Bozeman users move to the 800 MHz band, and the VHF band becomes less utilized as a result.

Motorola currently is developing a design, with cooperation from Mission Critical Partners, that would upgrade the VHF conventional systems to simulcast operation. This solution may not be needed if the benefits of 800 MHz trunking are realized by the County. Nevertheless, the design is moving forward and the option ready for procurement in the unlikely event that 800 MHz trunking system does not provide satisfactory coverage.

After seeing how the 800 MHz system performs, the County needs to decide which combination of 800 MHz trunking and VHF conventional stations are required to support radio operations in the county.

4 Conclusions

After reviewing the sites, observing the systems, and hearing about issues from several users and the radio support team, there are decisions that Gallatin County should commit to making towards a comprehensive communications plan involving the VHF and 800 MHz bands. There are several areas where the previous consultant's recommendations are accurate; specifically, their assessment of the 800 MHz band was accurate for the time. However, new technology has emerged that has been proven over the past two years that would give the County more choices than were available previously. Moreover, most of the issues that Gallatin County is experiencing are not new to the industry—many other rural areas have experienced these growing pains as they become increasingly urban, especially in radio communications.

In summary, Gallatin County can benefit from deploying dual-band radios and adding 800 MHz trunking capability to serve urban users, resulting in a more consistent and reliable communications platform for the county.

Final Report

9-1-1 Radio System Engineering Study

Prepared for
Gallatin County 9-1-1

Prepared by
Joe P. Blaschka, Jr., P.E.
Peter Abraham
Mike Norin
ADCOMM Engineering Company

Date Prepared
September 8, 2015

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September 8, 2015

Ms. Kerry O'Connell, Director
Gallatin County 9-1-1
1705 Vaquero Parkway
Bozeman, MT 59718

RE: Gallatin County 9-1-1 Radio System Engineering Project — Final Report

Dear Ms. O'Connell:

Please find attached the Final Report deliverable for the *Radio System Engineering* project. As one of six milestones and the final deliverable for the project, this report pulls together all of the individual reports developed by ADCOMM, including:

- Current State report *(originally delivered June 23, 2015)*
- Technology Review report *(delivered June 23, 2015)*
- High-Level Design and Strategic Directions report *(delivered July 20, 2015)*
- User Needs and Gap Analysis report *(delivered August 25, 2015)*

Please let me know if you or any of the other stakeholders have any questions or comments regarding the Final report.

It has been a pleasure working with Gallatin County and the various project stakeholders. Thank you for your business.

Sincerely,

ADCOMM Engineering Company

Joe P. Blaschka, Jr., P.E.
Principal

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Joe Blaschka, Jr., P.E.

Final Report

Gallatin County
9-1-1 Radio System Engineering Study
Technology Review

Prepared for
Gallatin County 9-1-1

Prepared by
Joe Blaschka, Jr., P.E.
Mike Norin
ADCOMM Engineering Company

Date Prepared
June 23, 2015

ADCOMM Engineering Company
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Contents

Figures

Acronyms and Abbreviations

ADCOMM	ADCOMM Engineering Company
DMR	digital mobile radio
EMS	emergency medical services
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FD	fire department
FDMA	frequency division multiple access
FirstNet	First Responder Network Authority
FM	frequency modulation
GHz	gigahertz
GPS	global positioning system
IP	Internet Protocol
LMR	land-mobile radio
LTE	Long-Term Evolution
MHSB	monitored hot-standby
MHz	megahertz
NTIA	National Telecommunications and Information Administration
P25	APCO Project 25
PD	police department
PSTN	public-switched telephone network
PTT	push-to-talk
RF	radio frequency
TDMA	time division multiple access
UHF	ultra high frequency
VHF	very high frequency
VoLTE	Voice over LTE

Technology Review

Executive Summary

As part of the Gallatin County 9-1-1 Radio System Engineering Study project (the "project"), ADCOMM Engineering Company (ADCOMM) evaluated a number of radio technologies and the viability of each with regards to an upgraded radio system for the county. This report details ADCOMM's findings.

Many two-way land-mobile radio (LMR) technologies and options exist today, some of which might be appropriate for use in an updated radio system for Gallatin County while others are not. In general, the primary technologies and options can be categorized by frequency band, system architecture, and air interface technology.

The primary public safety LMR frequency band options are low-band VHF (30 to 50 MHz), high-band VHF (150 to 174 MHz), UHF (450 to 470 MHz), 700 MHz, and 800 MHz, with each band having its own advantages and disadvantages. Since all users in the county currently use VHF, it would be advantageous for a new system to also be on VHF so at least some existing mobile and portable radio equipment could be reused. Unfortunately, it is most difficult to find usable new frequencies in the VHF band. It may be possible that at least some number of additional VHF channels could be licensed, but that may not be sufficient to meet the channel needs of users in the county. The VHF frequency congestion is made worse by the use of VHF by the State of Montana for their trunked radio system and the extensive use of the "color" VHF channels statewide for interoperability. As a result, costs notwithstanding, it may be preferable to deploy a new system using the UHF frequency band.

Numerous system architecture technologies are available, including standalone base stations and repeaters, receiver voting, transmitter steering, multicast, simulcast, trunking, and various combinations thereof. Given the size of Gallatin County, and to maximize frequency-use efficiency while reducing operational complexity, ADCOMM believes that simulcast technology (in conjunction with receiver voting) makes the most sense for the core areas of the county, primarily the Gallatin Valley, including Bozeman.

Further, with the relatively small number of channels needed, a conventional (non-trunked) system would likely be most cost-effective in meeting the needs of users in the county. Either analog FM or Project 25 (P25) digital could be used with such a conventional system. For channels where encryption is desired, P25 is recommended.

If a transition to UHF and/or P25 is undertaken, consideration must be given to interoperability and mutual aid, since the vast majority of surrounding counties and other mutual aid agencies would continue to operate on VHF analog.

In addition to the LMR system itself, there are various technology options available for providing radio site connectivity, or *backhaul*, such as microwave, fiber, telephone lines, radio frequency (RF) links, and control stations. To support a simulcast system, highly reliable and stable connectivity is needed. Wherever possible, ADCOMM recommends using licensed microwave systems; however, fiber and telephone company T1 circuits may also be viable in some circumstances.

To augment the existing or updated LMR system, agencies may also wish to consider limited use of vehicular repeaters, which can provide portable radio coverage where only mobile

service is available. Such repeaters have limitations, but they can be effective when used properly.

At this time, ADCOMM does not believe the *FirstNet* public safety broadband network will be a viable option for use in Gallatin County, particularly for push-to-talk (PTT) voice, any time in the foreseeable future.

Introduction

Project Purpose and Scope

In February 2014, ADCOMM was contracted by Gallatin County to perform a radio system study. In general, the purpose of this project was to determine the state of the existing public safety two-way radio communication systems in use by stakeholders in the county, identify the operational needs of the radio systems' users, identify potential technologies and their applicability to a replacement/upgraded radio system, and develop a high-level system design for such a system, followed by solution selection and implementation preparation.

Based on this contract, the project consists of the following phases:

1. **Phase One: Information Gathering and Education.** The deliverables of Phase One are the Current State Report, the User Needs and Gap Analysis, and the Technology Review ***(this report)***. The purpose of this phase is to generate information needed by ADCOMM and by stakeholders to fully understand the existing systems, both for comparison purposes and to identify the needs of the systems' users.

2. **Phase Two: Solution Development.** Using the information gathered during Phase One, Solution Development's deliverable is a list of potential solutions, with rough order of magnitude costs, to the challenges faced by Gallatin County's radio systems. The end of Phase Two is a joint meeting to discuss and evaluate each of the potential solutions, with the County decided on one or more potential solutions for further development. Selection of the solution at this stage begins to set the strategic direction.

3. **Phase Three: Strategic Direction and High-Level Design.** During Phase Three, the selected solution is developed further to yield a strategic direction document and a high-level design. The solution will be divided into a series of implementable modules, with estimated costs, implementation time, and impact to the voice systems identified. The High-Level Design will be sufficient to drive the detailed engineering needed as the first step toward acquisition and implementation.

4. **Phase Four: Final Study Report.** The Final Study Report is a combination of all the deliverables created in the project with a summary and explanatory text for use in grant justifications and budget discussions. ADCOMM anticipates an in-person delivery of the final report to Gallatin County decision makers and stakeholders at a combined meeting.

5. **Phase Five: Solution Selection and Implementation Preparation.** Following the Final Study Report release, stakeholders will meet to identify specific solutions for implementation. These solutions will be further developed to produce engineering drawings, detailed system price estimates, and technical specifications for use in procurement and implementation. Solution development will be for voice radio system changes only.

Note that the following are not included in the scope of work for the current project: technical procurement reviews and assistance, vendor selection, technical support during contract negotiations, implementation engineering services, and/or project management.

Technology Review

The goal of the Technology Review is to provide Gallatin County with an overview of current and future technologies in voice radio systems, along with an evaluation of each technology's applicability in the County's circumstance. The Technology Review is intended to give Gallatin County decision makers a firm foundation in the technologies that are available so informed decisions can be made in the Strategic Direction portion of the project. Options for frequency bands, system architectures/access configurations, and modulation modes are discussed. In addition, brief discussions of backhaul technology options and other technology considerations are included.

Overview

Many different two-way radio technologies and options exist today, some of which would be appropriate for use in Gallatin County while others are not generally recommended. For the LMR system that users access directly with their radios, these technologies and options can be categorized by frequency band, system architecture (including distribution configuration and system access configuration), and modulation mode or air interface technology. Each of these categories are described and examined in relation to the Gallatin County radio project in the next sections of this report.

In addition to the LMR system itself, there is a variety of technology options available for providing radio site connectivity (backhaul), such as microwave, RF links, control stations, etc. A description and evaluation of each of the primary connectivity methods is also included.

Lastly, there are other technologies available that can be used to augment a standalone LMR system, such as vehicular repeaters, alphanumeric paging (currently used by Gallatin County), and perhaps at some point in the future even a potential replacement of private LMR systems altogether by the First Responder Network Authority ("FirstNet"). A description of these technologies and their viability is included as well.

LMR System Technologies and Options

Frequency Bands

Numerous frequency bands have been assigned by the Federal Communications Commission (FCC) for LMR use. Each of the bands detailed below has frequencies allocated for public safety use, as would be appropriate for Gallatin County's radio system.

Low-Band VHF

The low-band VHF frequency band, commonly referred to simply as "low band," consists of spectrum in the 30 to 50 MHz range. Although it can provide better coverage in areas with hilly and mountainous terrain compared to other frequency bands, there are significant issues related to low band. Because of these issues, low band is no longer commonly in use.

One issue with low band is that it is significantly more susceptible to propagation "skip" than the other frequency bands. Under *skip* conditions, co-channel users can be heard and cause interference from distances of hundreds or even thousands of miles. Skip is often unpredictable and little can be done to control it.

Another issue with low band is that antennas and filtering equipment is much larger than with other bands. This can impact tower loading as well as equipment shelter space utilization. For example, low band cavity filters can be 7 to 8 feet tall, whereas a VHF high band cavity might be 3 feet tall.

Further, because of the limited demand for low band equipment, there are a limited number of suppliers of low band fixed infrastructure equipment (i.e., repeaters, base stations, antennas, filters, etc.) as well as subscriber equipment (i.e., mobile and portable radios).

If low band were to be used by Gallatin County, all radio infrastructure and subscriber equipment would need to be replaced. In addition, interoperability with surrounding agencies using other frequency bands (most commonly *high-band* VHF) would be impeded with a change to low band.

Because of the significant number of downsides, **ADCOMM does not recommend Gallatin County pursue a low-band solution.**

High-Band VHF

The LMR high-band VHF frequency band, commonly referred to simply as "VHF," consists of spectrum in the 150 to 174 MHz range. Many public safety as well as industrial/business systems use VHF, including virtually all public safety users in Gallatin County. Although it does not provide coverage as effectively as low band in hilly and mountainous areas, VHF does provide somewhat better non-line-of-sight coverage than UHF, 700 MHz, and 800 MHz.

While not totally immune from it, VHF frequencies suffer far less from skip than low band. On the other hand, in all but the most remote locations, the VHF band suffers from a high noise floor, which has a direct impact on radio system performance, effectively reducing usable range or coverage. Measurements taken by ADCOMM confirmed that the noise level at many locations in Gallatin County is relatively high, particularly at several radio sites and at various locations in and around Bozeman and Belgrade.

Another one of the more significant issues with VHF is limited frequency availability. This is partly due to the band's popularity, but it is further impacted by the lack of an efficient *band plan*.[1] For instance, it is possible to have one VHF frequency be used as a repeater transmit ("output") frequency by one licensee and as a mobile transmit/repeater receive ("input") frequency by another licensee some distance away, potentially creating interference between the two systems.

In most areas of the country, it is difficult at best—or not feasible at all—to deploy a *trunked* radio system at VHF due to the limited frequency availability and the co-channel spacing requirements for a trunked system. Although the Montana "state" trunked VHF radio system has sites in and around Gallatin County, expansion of this system in Gallatin County with additional frequencies may not be possible due to the *exclusive-use* frequency coordination requirements for a trunked system. Even for a conventional (non-trunked) system, depending on how many total channels are desired, there may not be a sufficient number of VHF frequencies available to meet Gallatin County's needs.

[1] FCC band plans define how the frequencies in a particular band may be used, particularly in regard to *base transmit* and *mobile transmit* use. Efficient band plans group base transmit frequencies in one part of a band and mobile transmit frequencies in another part of a band and include frequency separation between the two. Inefficient band plans allow for more haphazard use of frequencies within a band.

Because agencies in Gallatin County already use VHF, depending on whether the upgraded system uses analog or P25 digital, it may be possible to reuse many of the existing mobile and portable radios, thus reducing the overall project cost. Further, interoperability with surrounding agencies that continue to use VHF would be unaffected. Due to its popularity, VHF infrastructure and subscriber equipment is readily available from numerous manufacturers.

Because of the existing inventory of subscriber units, favorable propagation characteristics, and interoperability, **ADCOMM believes using VHF could be a viable option for Gallatin County but only if a sufficient number of frequencies can be licensed. Due to the high noise floor and lack of available frequencies, however, VHF would not be ideal.**

UHF

The UHF frequency band for LMR operations consists of spectrum in the 450 to 470 MHz range. Many public safety and industrial/business systems use UHF, although somewhat less so in more rural areas including Montana. Because they are higher frequencies, UHF does not generally propagate as far as VHF or low band. As a result, in some cases a greater number of sites may be required to provide comparable coverage. On the other hand, the noise floor at UHF tends to be lower than at VHF, which can make up for some or all of the reduced coverage. Further, due to its shorter wavelength, in-building coverage at UHF is often better than at VHF.

As with VHF, UHF infrastructure and subscriber equipment is readily available from numerous manufacturers. In addition, particularly in more rural areas, there is better availability of UHF frequencies due to its lower popularity as well as having an efficient band plan. In some areas around the country, it is still feasible to deploy trunked systems at UHF due to having better frequency availability. There are likely a sufficient number of UHF frequencies available in Gallatin County for an upgraded conventional system or conceivably even a trunked system.

Because Gallatin County does not currently use UHF, all new radios would need to be purchased, significantly increasing overall project costs. Further, since the vast majority of surrounding agencies would still be using VHF, interoperability would be impacted, likely requiring some users to carry multiple radios or more expensive dual-band radios.

ADCOMM believes UHF would be a good option for Gallatin County if interoperability and the costs for new subscriber radios can be managed.

700 MHz

The 700 MHz *narrowband* LMR frequency band consists of spectrum in the 769 to 775 MHz and 799 to 805 MHz ranges.[2] The 700 MHz band is reserved for use by public safety and governmental entities; there are no industrial/business channels. Compared to the other LMR bands, 700 MHz is the "newest," having been allocated by the FCC to public safety in the early 2000s in conjunction with the subsequent transition to digital broadcast television. All *general-use* channels in the 700 MHz LMR band are required to use digital modulation (e.g., P25); analog is not permitted.

The biggest advantage of the 700 MHz band is frequency availability, with no known current use in Montana. Unfortunately, 700 MHz propagates even shorter distances than UHF. While suitable for many urban and suburban environments, a potentially significant number of

[2] This does not include the 700 MHz *broadband* spectrum reserved for the nationwide FirstNet public safety long-term evolution (LTE) network.

additional sites could be required to provide the necessary coverage, particularly in the rural and mountainous areas of Gallatin County.

As with UHF, the purchase of new 700 MHz mobile and portable radios would be required for all agencies. Interoperability with surrounding agencies would also be complicated by a move to 700 MHz.

Because of the greater number of sites required, high subscriber unit replacement costs, and interoperability issues, **ADCOMM does not recommend 700 MHz for Gallatin County.**

800 MHz

The 800 MHz LMR frequency band consists of spectrum in the 806 to 821 MHz and 851 to 866 MHz ranges. Propagation characteristics of 800 MHz are similar to 700 MHz, thus an 800 MHz system would require essentially the same number of sites as a 700 MHz system. In fact, many systems today use a mix of 700 and 800 MHz channels to meet their capacity requirements. Unlike 700 MHz, analog modulation is permitted on 800 MHz channels. Note that there are no manufacturer-supported analog trunked options available (only conventional analog is supported).

The only known 800 MHz public safety system in Montana is operated by the City of Billings. As such, there would be no issue with licensing a sufficient number of 800 MHz channels for a new system in Gallatin County. As with 700 MHz, though, additional sites would be required to provide comparable coverage to VHF or even UHF, thus increasing system costs.

Since there are no 800 MHz radios in use today, new mobile and portable radios would be needed for all agencies. In addition, interoperability with surrounding agencies would be impeded with a shift to 800 MHz.

As with 700 MHz, because of the greater number of sites required, high subscriber replacement costs, and interoperability issues, **ADCOMM does not recommend 800 MHz for Gallatin County.**

System Architectures

Radio system architectures can be broken into two primary access configurations: *conventional* and *trunked*. The key difference between these two configurations is how frequencies are assigned to users and their associated transmissions. In addition, there are various technologies available for providing wide-area coverage, including receiver voting, simulcast, multicast, and transmitter-steering, which are often used in conjunction with both conventional and trunked systems. This section describes each of these technologies, their associated advantages and disadvantages, and potential applicability to Gallatin County.

Conventional Base Station Systems

Conventional base station simplex radio systems are the simplest form of VHF and UHF *frequency modulation* (FM)[3] LMR communications technology today and have stayed relatively the same since the 1950s. Base station, mobile, and portable radio communication range are all limited by line-of-sight and signal propagation. Simplex systems use one frequency per channel (see Figure 1). Conventional base stations are not used on any of the main Gallatin County dispatch channels.

[3] Frequency modulation is a method of transmitting information on an analog channel by varying the carrier frequency.

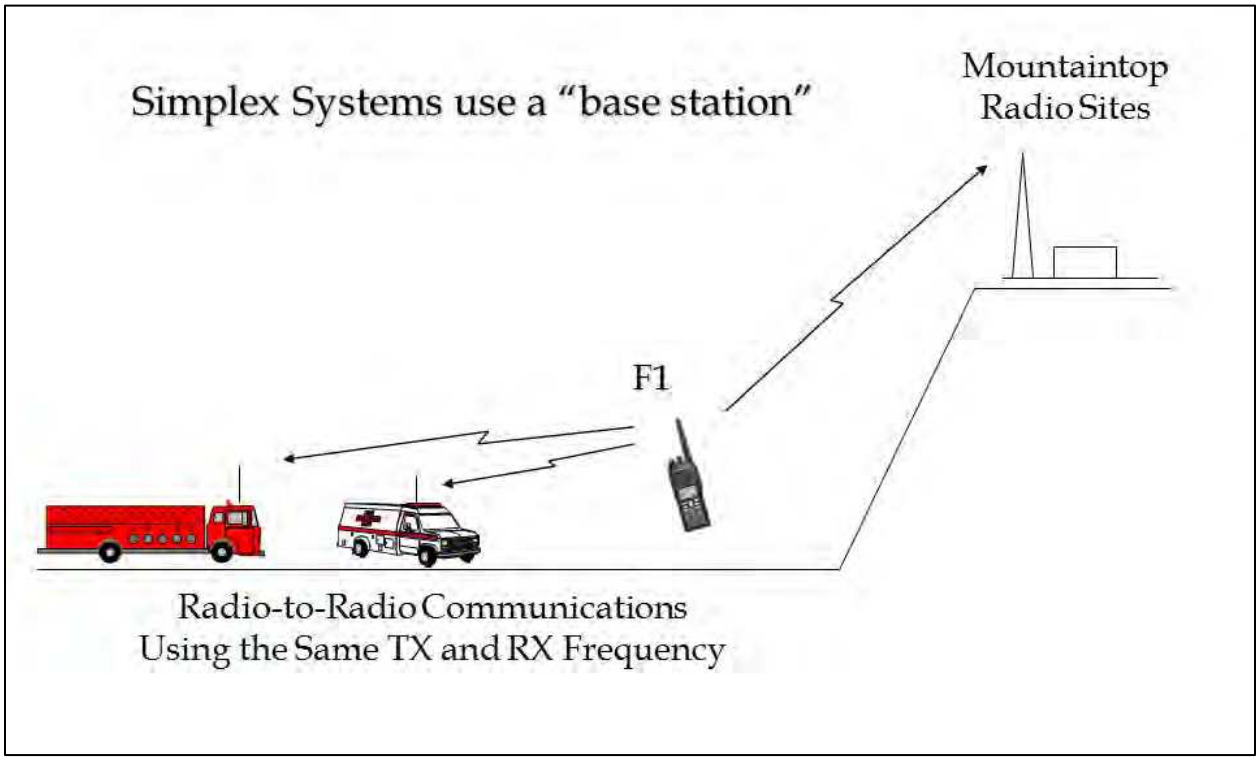

FIGURE 1
Simplex Base Station System

Advantages

- The use of a single base station is the least-cost technology solution to provide limited area communications coverage.

Disadvantages

- Single conventional base stations on mountaintops require microwave or telephone control circuits.
- Multiple conventional base stations must be strategically located throughout the desired service areas.
- The use of a single conventional base station may not provide the necessary radio coverage required in the desired service areas (see Figure 2).
- A mobile or portable radio user can interfere with dispatcher transmissions.
- Multiple conventional base stations on the same frequencies using different CTCSS require dispatcher and user training so that the correct base station is used in the specified operating area. As an example, it is possible for a radio user to respond back to a dispatcher on a base station that does not have overlapping coverage. This condition may cause missed communications and confusion.

Due to their limited capability and coverage, **ADCOMM does not recommend Gallatin County use conventional base stations for its system upgrade.**

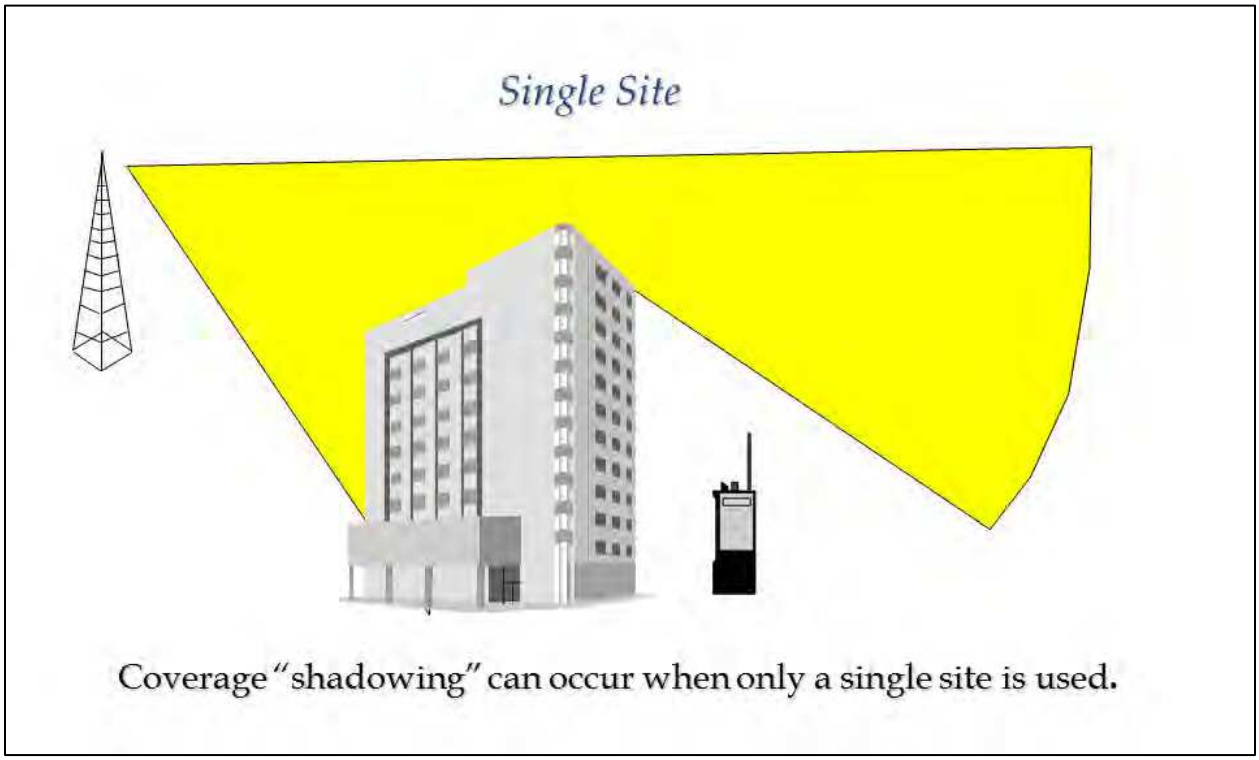

FIGURE 2
Single-Site Coverage

Conventional Repeater Systems

Conventional repeater systems extend the range of mobile and portable radios by receiving a low power signal, amplifying the signal, and automatically retransmitting it at a higher power level. Repeaters are often located on mountaintops or buildings to increase the radio coverage. Repeater systems use two frequencies per channel (see Figure 3). The vast majority of the existing radio systems in Gallatin County employ conventional repeaters.

Advantages

- The use of a single conventional repeater is the least-cost technology solution to provide limited area communications coverage while allowing a dispatcher and other radio users to hear both sides of a conversation at the same signal strength.
- Single conventional repeaters can be standalone devices that do not require microwave or telephone control circuits.
- Multiple conventional repeaters can be strategically located throughout the desired service areas.

Disadvantages

- The use of a single conventional repeater may not provide the necessary radio coverage required in the desired coverage area (see Figure 2).
- A mobile or portable radio user can interfere with dispatcher transmissions.
- Multiple conventional repeaters on the same channels require dispatcher and user training so that the correct repeater is used in the desired coverage area. As an example, it is possible for a radio user to respond back to a dispatcher or other radio user on a repeater that does

not have overlapping coverage. This condition may cause missed communications and confusion.

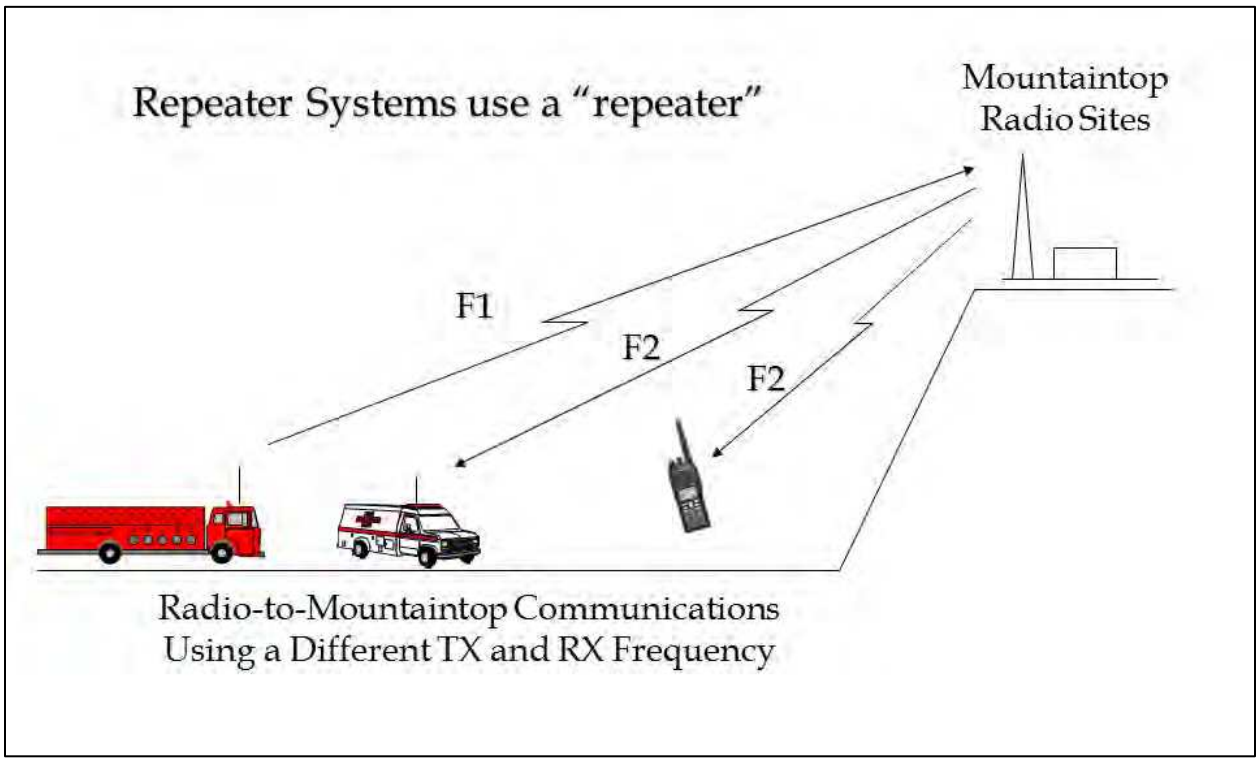

FIGURE 3
Repeater System

Although not as ideal in some situations as other technologies, such as simulcast or multicast, given their affordability and relative ease of deployment, **ADCOMM believes the strategic use of conventional repeaters continues to be appropriate for addressing portions of Gallatin County's communication needs**, particularly tactical uses and in very rural areas with relatively low usage.

Voting Receiver Systems

A voting receiver system has dedicated radio receivers that are strategically located so one or more of the receivers will receive a good quality signal from a mobile or portable radio transmitting from anywhere in a desired service area. The output of the receivers is connected to a centrally located device called a voting comparator (or "voter"). Because the same signal may reach several voting receivers at once, the comparator continuously compares the received signals, selects the receiver with the best audio quality, and then routes the receive audio to a dispatcher and/or repeater transmitter. The selection and change-over from one receiver to another is rapid enough to prevent loss of any words. Voting receivers are normally co-located with repeater transmitters or can be located as a standalone receiver in critical coverage areas (see Figure 4).

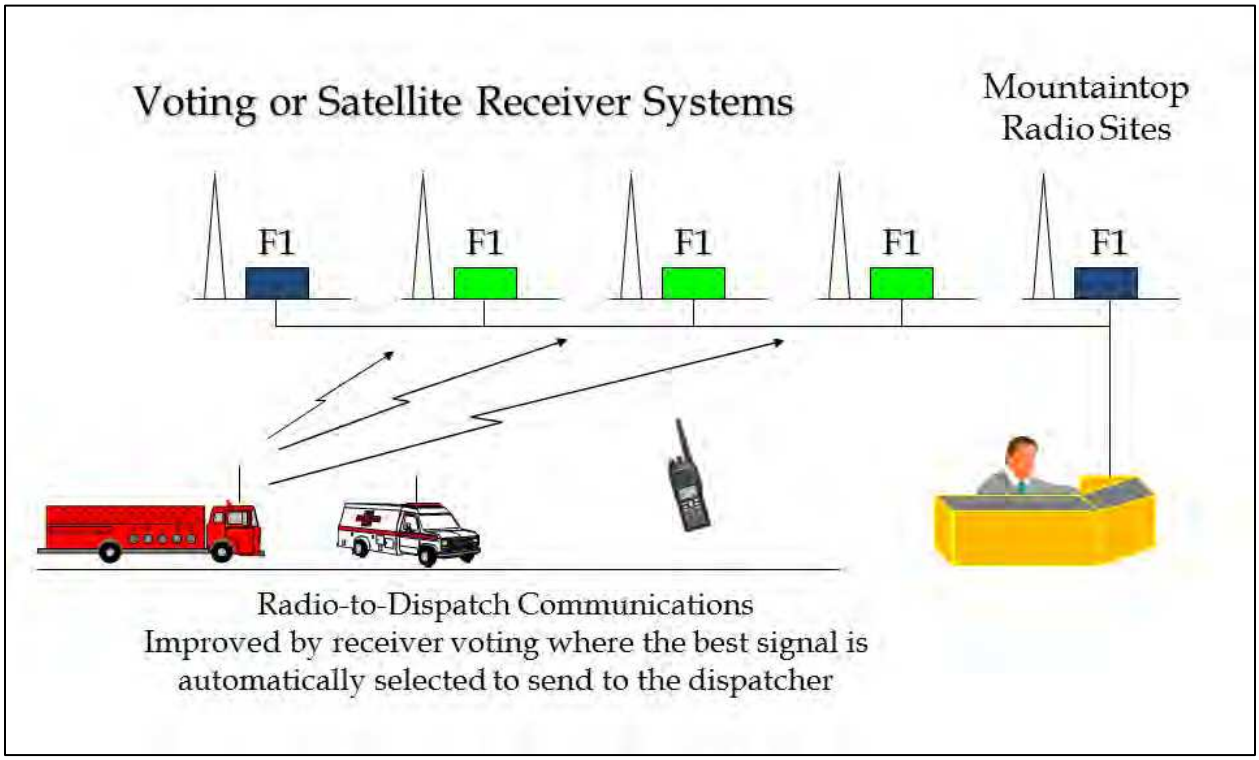

FIGURE 4
Voting Receiver System

It is common for a low-power portable radio to hear a high-power repeater yet be unable to talk to a dispatcher or other radio user on a repeater system because of a weak talk-in signal. A repeater system with numerous voting receivers can greatly improve portable radio communications in the specified operating area of the transmitter.

Currently in Gallatin County, voting receiver systems are used with the Bozeman PD, Law North, and Fire North channels.

Advantages

- The benefit of a voting receiver system is to extend the talk-in or talk-back range from low power radios in the field to the dispatcher and other radio users on the repeater system.
- Radio users do not need to remember to switch between radio sites to communicate with a dispatcher or other radio user when using a single channel voted radio system.

Disadvantages

- A dedicated communications link must connect the dispatch center with each radio site.
- Costs more than constructing multiple standalone repeater systems.
- Requires higher levels of preventive maintenance and operating costs.

With their effectiveness at improving talk-in coverage from field users and simplifying radio and dispatch operations, **ADCOMM believes expanded use of voting receivers would be an extremely beneficial part of any radio system upgrade for Gallatin County.**

Dispatcher-Controlled Repeater Transmitter Steering Systems

A dispatcher-controlled transmitter steering system can be used in conjunction with a receiver voting system. One of the methods of preventing interference with multiple repeaters sharing

the same channel is to allow only one repeater transmitter site to be active at one time. This can be controlled by the dispatcher via a dispatch console (see Figure 5).

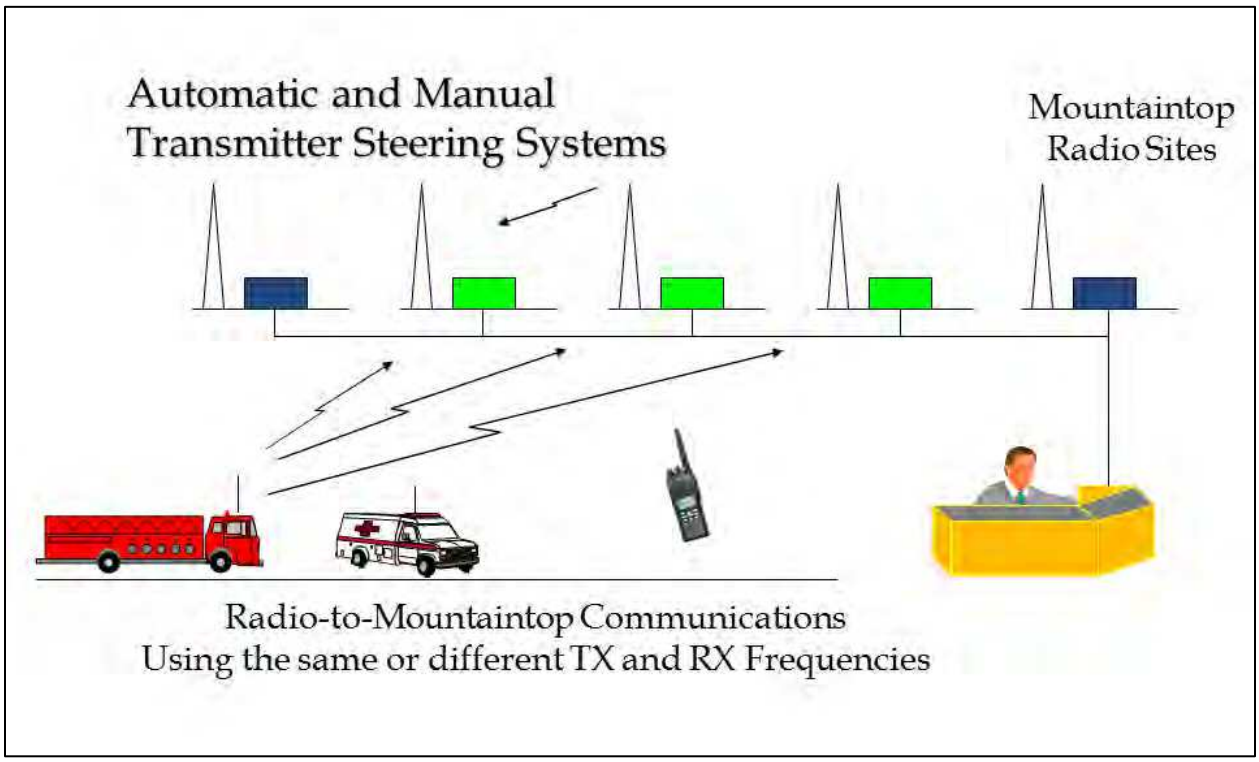

FIGURE 5
Automatic/Manual Transmitter Steering System

Currently, Gallatin County's Fire North channel is a transmitter steering system whereby a 9-1-1 dispatcher can manually select a transmitter at one of five remote sites depending on the location of the incident or field user(s) being contacted. Voting receivers are also used on the Fire North channel to improve talk-in coverage.

Advantages

- Can eliminate the possibility of two users keying up two different repeaters at the same time causing interference between repeaters.
- The dispatcher can select the best repeater transmitter to a single or group of mobile or portable radio users.
- Less expensive than other advanced wide-area coverage systems.

Disadvantages

- A dedicated communications link must connect the dispatch center with each remote radio site.
- One repeater transmitter cannot provide the radio coverage throughout the desired service area. There may be times when two units that need to intercommunicate are separated over enough distance they cannot hear each other because the single site does not provide adequate coverage.
- The dispatcher must know the coverage area of each selectable repeater transmitter and the location of the field unit.

- Dispatchers performing other duties and may be unable to switch the transmitter between the sites to provide the necessary radio coverage.
- As the dispatcher switches the active transmitter between sites, some radio users may miss important communications because the selected transmitter may be weak in their area.

Due to the number of sites that are required to effectively cover Gallatin County or even just the northern portion of the county, expanded use of transmitter steering systems would generally only serve to increase operational complexity while not always being effective in providing the necessary coverage. As such, **ADCOMM generally does not recommend manual transmitter steering systems as a primary system architecture for Gallatin County's updated radio system.** That said, depending on the chosen frequency band and its associated frequency availability, transmitter steering could still be an option for covering southern Gallatin County, albeit less preferred than other options such as simulcast or multicast.

Automatic Transmitter Steering Systems

An automatic transmitter steering system is normally used in conjunction with a receiver voting system. It operates on the theory the best transmitter site to reach a particular mobile or portable radio user was also the last site that received the best signal. When a mobile user calls a dispatcher, the voting system comparator selects the best audio quality receiver. On the assumption the dispatcher will immediately answer the mobile radio user that just called, the transmitter steering system remembers the last receiver the voting comparator selected and automatically selects the transmitter co-located with the voting receiver site. If standalone receivers are deployed, the transmitter steering controller system can be preprogrammed to use a transmitter for a group of receivers in a specified operating area. A default transmitter location can also be selected for an initial "first of day" dispatch (see Figure 6).

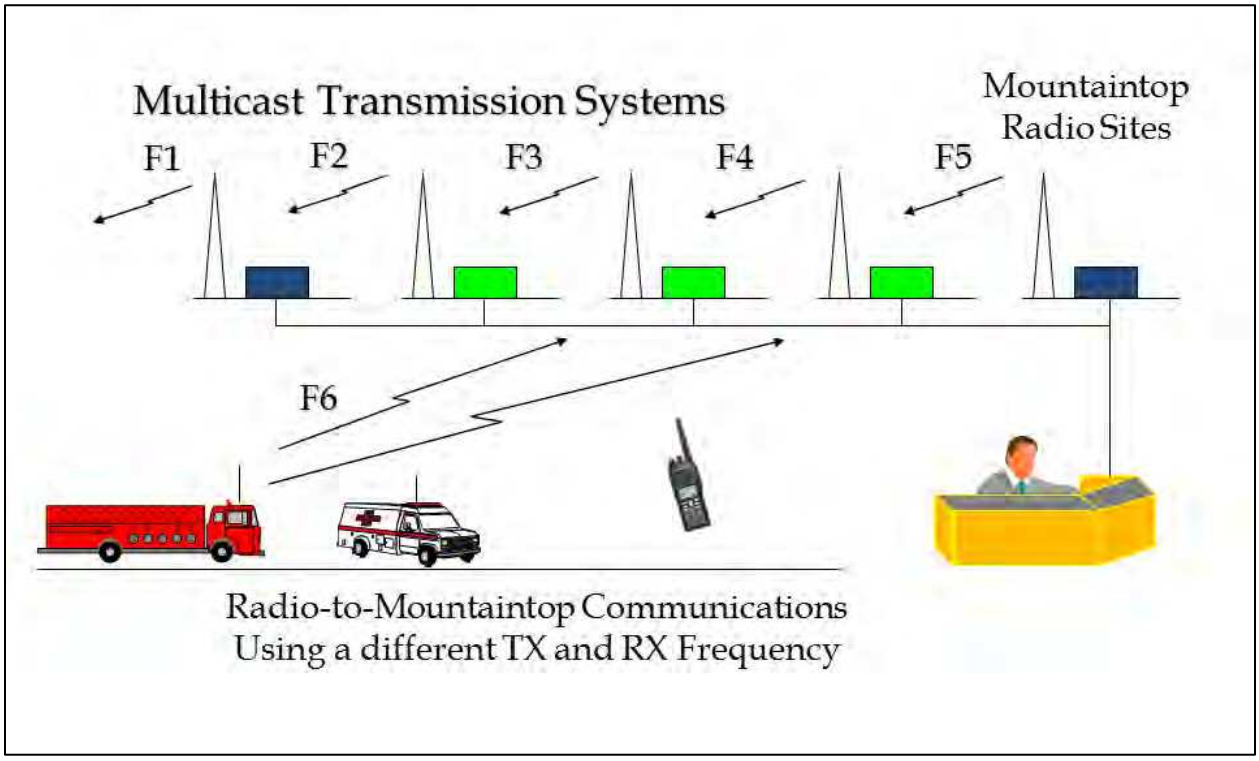

FIGURE 6
Multicast Transmission System

Currently, Gallatin County's Fire North channel is a transmitter steering system that has the ability to automatically select a transmitter site based on the receiver most recently selected by the voting comparator. The default transmitter site for Fire North is Bridger Ridge.

Advantages

- Transmitter steering is a relatively inexpensive way to have the benefits of multiple transmitter sites.
- Less expensive than other advanced wide-area coverage systems.

Disadvantages

- A dedicated communications link must connect the dispatch center with each radio site.
- The comparator could make the wrong decision because of a weak signal received simultaneously by multiple receivers. This could cause the faraway transmitter to be automatically selected and in turn could cause the response from a dispatcher or other radio users to be unreadable.
- Another condition that could cause the wrong automatic transmitter selection is when a second radio user calls a dispatcher just before the dispatcher responds to the first radio user. The first radio user may not hear the dispatcher because of a faraway transmitter being selected by the last transmission of the second radio user.

Transmitter steering systems can be made to work successfully in the right application. A typical application where it will work the best is an area where there is significant transmitter overlap and most of the communications are initiated by the mobile unit to the dispatch center.

Due to the number of sites that are required to effectively cover Gallatin County or even just the northern portion of the county, expanded use of transmitter steering systems would generally only serve to increase operational complexity while not always being effective in providing the necessary coverage. As such, **ADCOMM does not generally recommend transmitter steering systems as a primary system architecture for Gallatin County's updated radio system.** Again, depending on the chosen frequency band and its associated frequency availability, automatic transmitter steering could potentially be an option for covering southern Gallatin County, albeit a less preferred option than simulcast or multicast.

Multicast Transmission Systems

Multicast technology can be used when an abundant number of radio frequencies are available. Multicast is a wide-area radio system configuration using simultaneous transmissions of identical audio on separate frequencies from each transmitter site. Each transmitter is equipped with a receiver, and a receiver voting system is then used to select the best received signal. Multicast technology is a spectrum-*inefficient* technology (see Figure 6).

Multicast is not currently used in Gallatin County.

Advantages

- Dispatchers do not need to worry about transmitter selection.
- Less expensive than simulcast technology.

Disadvantages

- Radio users need to switch channels as they traverse the various radio coverage areas.
- A dedicated communications link must connect the dispatch center with each repeater radio site.

- Costs more than constructing multiple standalone repeater systems.
- Requires higher levels of preventive maintenance.

Practically, there are an insufficient number of VHF frequencies available to deploy multicast in Gallatin County, except perhaps in the southern part of the county. Even at UHF, given the number of channels desired and number of sites required for coverage, there are likely an insufficient number of frequencies available except for southern Gallatin County. As such, **ADCOMM believes multicast is not a practical option for Gallatin County, except perhaps to cover the southern part of the county if simulcast is not viable there.**

Simulcast Transmission Systems

Simulcast technology has been in existence since approximately the 1960s. However, the technology has improved significantly in recent years to the point where the maintenance issues have been reduced to manageable levels. Simulcast technology allows the use of the same frequency to transmit the same information simultaneously from multiple radio sites with overlapping coverage. Simulcast is basically "controlled interference" from multiple transmitters. This is accomplished by having accurate frequency control, audio phase, and amplitude control from the transmitters. A two-way radio system using simulcast technology always uses a receiver voting system. Simulcast uses multiple transmitters usually operating at lower power levels spread throughout the specified service area to improve coverage. Each transmitter is equipped with a receiver, and the receiver voting system is used to select the best received signal (see Figure 7 and Figure 8).

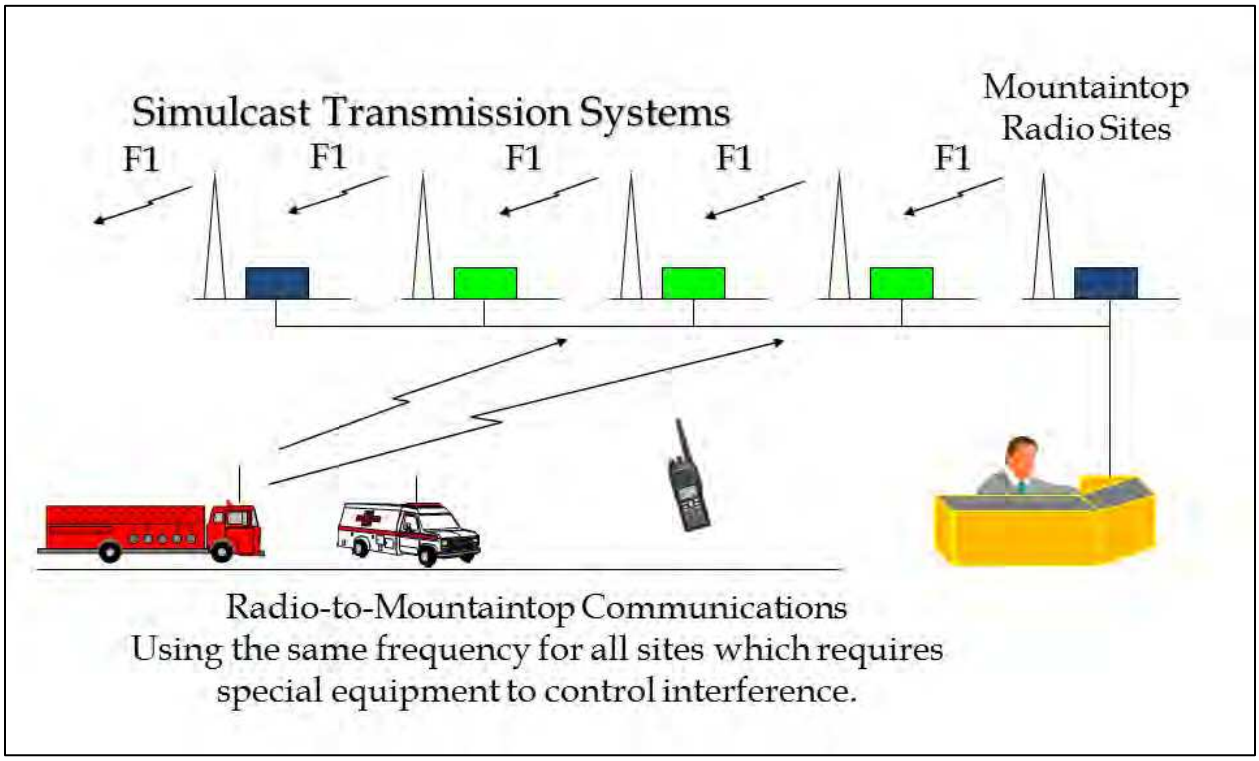

FIGURE 7
Simulcast Transmission System

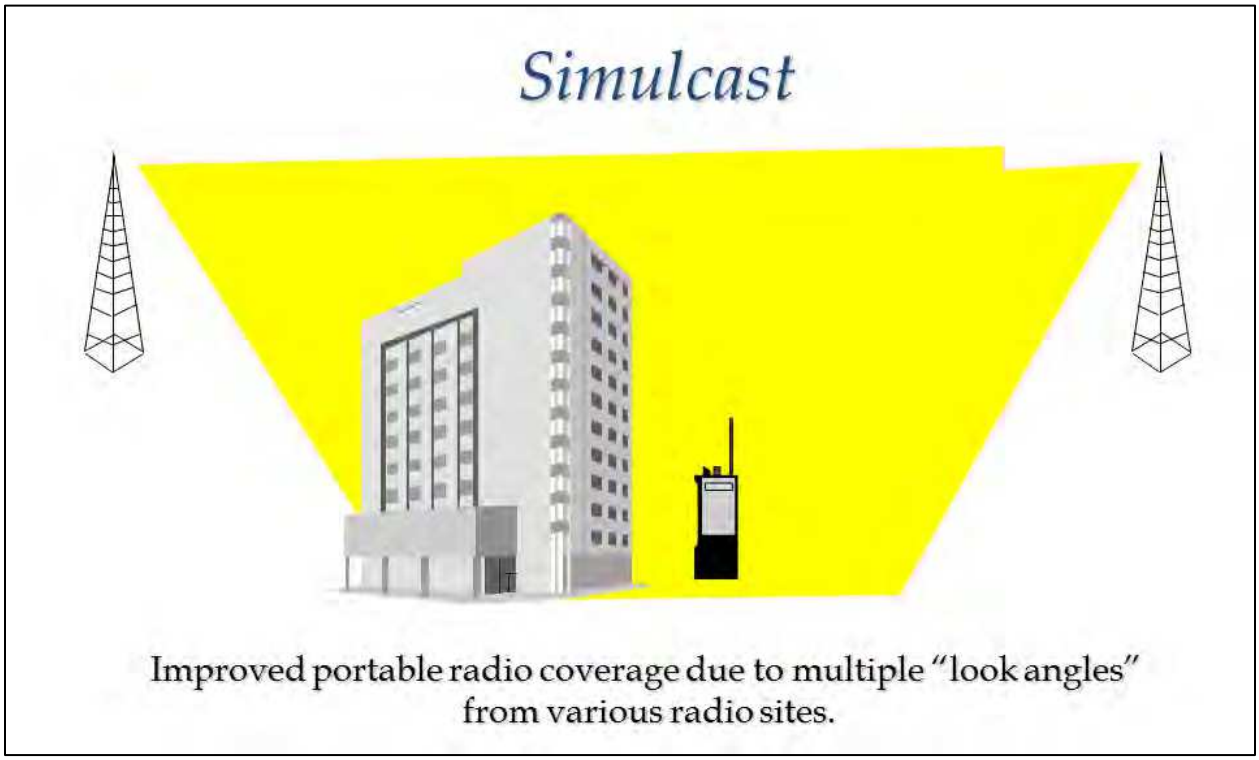

FIGURE 8
Simulcast Coverage

Simulcast technology is a spectrum-*efficient* technology because it allows the use of lower power transmitters thus reducing the amount of signal that travels outside the operational area, and it allows wide areas to be covered by a single frequency. Simulcast is relatively expensive to implement because of the special techniques required. It is used on many public safety systems and virtually all wide-area alphanumeric paging systems, both commercial and private.

To a dispatcher or radio user in the field, simulcast technology acts like a single transmitter with wide-area coverage. Unlike manual or automatic transmitter steering, no dispatcher or radio user intervention is required.

Currently in Gallatin County, simulcast is only used with the alphanumeric paging system.

Advantages

- Dispatchers and radio users do not need to worry about transmitter selection.
- If desired, a single radio channel can have countywide radio coverage.

Disadvantages

- A dedicated communications link must connect the dispatch center with each repeater radio site.
- Costs more than constructing multiple standalone repeater systems.
- Requires higher levels of preventive maintenance.

Due to limited frequency availability, the number of channels desired, and the dramatically improved coverage and ease of user operation, **ADCOMM believes simulcast technology is preferred as a foundation of Gallatin County's upgraded radio system.**

Trunked Radio Systems

Trunked technology was originally developed in the late 1800s and early 1900s as the basis of the public-switched telephone network (PSTN) still used today (circuit switched, not IP[4] based). Trunked radio technology has only been around since approximately 1980, facilitated primarily by the development and use of small and inexpensive microprocessors in mobile radios.

Trunked radio technology is commonly used when a limited number of radio frequencies are available. Trunked technology is spectrum-efficient because trunked systems distribute the radio users among all of the available frequencies automatically. This provides much better utilization of the limited frequency resources as compared to conventional systems, whose channel resources can go unused even when there is a demand for service on other channels. The actual assignment of a frequency is not under the control of the radio user or dispatcher. The term *talkgroup* is used to identify a virtual communications channel. It is possible to have more talkgroups than actual radio frequencies on a trunked radio system. The trunking control computer assigns a talkgroup to a particular frequency for communicating. When a talkgroup is not being used, it does not use system resources. In most cases, a dedicated data channel is used to communicate the channel assignments and special features between the controller and each radio on the trunked system. Originally most trunked systems used proprietary technology, but most recent systems, in particular those that are P25-based, use standards-based technology.

Trunked user radios are typically capable of having between 48 and 1000+ talkgroups, depending on the radio brand and model. Trunked technology is generally expensive to implement and manage. Most trunked systems require regular system controller and software updates, typically unnecessary with conventional systems. Simulcast technology is often also deployed by many trunked system vendors. Trunked technology is used on many public safety systems throughout the world.

None of the Gallatin County's primary radio systems is trunked. However, the Montana "state" radio system, portions of which have been inherited by Gallatin County, is a trunked system.

Advantages

- Spectrum-efficient when limited frequencies are available.
- Dispatchers and radio users do not need to worry about frequency selections.
- Advanced communications features commonly come standard with most trunking systems.

Disadvantages

- A dedicated communications link must connect the dispatch center with each repeater radio site.
- Costs more than constructing multiple standalone repeater systems.
- Requires higher levels of preventive maintenance and upgrades.

Because of the relatively small number of channels needed by users in Gallatin County, the high initial and ongoing costs and complexity of a trunked system likely cannot be justified at this time.

Modulation Modes (Air Interface)

In addition to having multiple frequency band and system architecture options, there are several modulation mode (air interface) options available for LMR systems. The air interface is

[4] IP, or Internet Protocol, is a network and transport protocol used for exchanging packet data over a network, such as the Internet.

the radio-based link between the subscriber units and the base stations and/or repeaters. There are two primary categories of air interface: analog and digital. Analog radio technology has been in use for nearly 100 years and has fundamentally changed very little. On the other hand, digital radio technology has been used in earnest for less than 20 years and comes in many varieties, most of which are not compatible with one another. The following sections describe the most common LMR air interface technologies and their viability with regards to the Gallatin County radio system upgrade project.

Analog FM

Even with significant moves toward digital technology around the country, analog FM is still the most commonly used LMR air interface. Gallatin County's primary dispatch channels operate in analog mode, as do those of most surrounding mutual aid agencies. Widespread use of analog technology facilitates straightforward interoperability.

With the continued move toward digital systems, many manufacturers are dropping support for certain analog systems, particularly trunked analog systems. Conventional analog repeaters, base stations, and subscriber units are still widely available and are generally less expensive than comparable digital versions. A wide variety of analog mobile and portable radios are available at a variety of price-points, with all generally being compatible with one another.

One advantage of analog technology is that, unlike digital, it is compatible with tone/voice alerting systems, although such systems are no longer used by fire and EMS agencies in Gallatin County (the alphanumeric paging system is used for alerting). In addition, even though analog voice signals can get "scratchy" in weak coverage areas or become difficult to understand when interference is present, oftentimes a transmission can still be understood, or at the very least the users know a transmission was attempted and a retry can be requested. This often is not the case with digital systems.

Limited encryption options are available for analog radio systems and are often not standards-based. Range and intelligibility are often impacted with analog encryption systems. P25 digital is a much better option for encrypted communications.

If minimizing costs is a primary factor and encryption and/or trunking is not needed, analog FM could be an appropriate technology for some or all radio channels in Gallatin County.

Project 25 Digital

Project 25 is a suite of open standards for digital two-way radio communication typically used by public safety agencies in North America. Development of the standards started in the early 1990s and continues today. P25 is intended to ultimately provide a foundation for interoperability. However, its use is not mandated, and it should not be considered a "silver bullet" for interoperability. Users must not only have P25-capable equipment but their equipment must also operate on the same frequency band(s) as the agencies they intend to interoperate with. For example, a VHF P25 radio *cannot* communicate with an 800 MHz P25 radio, even though they are both P25-capable (unless, of course, multi-band radios are used). As P25 infrastructure is deployed in more areas, interoperability is expected to improve. However, it will still be many years, if ever, before P25 reaches all parts of the country, particularly in rural areas. This is primarily due to the significant expense of replacing analog infrastructure and subscriber equipment with P25 equipment.

There are two primary variants of P25: *Phase 1* and *Phase 2*. P25 Phase 1 uses a 12.5 kHz narrowband-compliant *frequency division multiple access* (FDMA) digital air interface, whereby

each channel supports a single talk-path. P25 Phase 2 is a newer technology that uses a 6.25 kHz-equivalent narrowband-compliant two-slot *time division multiple access* (TDMA) digital air interface, which support two talk-paths in each 12.5 kHz channel.

At least a basic level of compatibility exists between all vendors' P25 equipment, allowing end users to have a choice when selecting equipment. However, many vendors also offer proprietary "features," which if relied upon can consequently reduce equipment choices. All P25 Phase 2 radios are capable of also operating in Phase 1 mode, providing backward compatibility if configured properly. Further, all P25 radios are capable of analog operation. With proper equipment programming, user training, and procedures, this can reduce issues interoperating with surrounding agencies that are still using analog systems.

Digital Audio

P25 systems employ digitally encoded audio using a process known as *vocoding* ("voice encoding"). Compared to a traditional analog system, digitally vocoded audio improves the spectral efficiency and thus the capacity of the system, while also enabling features such as background noise cancellation. One of the primary advantages of P25 is the ability to use standards-based encryption, with no loss in audio quality or range compared to unencrypted operation. By comparison, analog encryption techniques normally result in a reduction in audio quality and/or coverage.

Because of the way it reproduces audio, digital systems sound *different* than analog systems. Whether it is better or worse than analog is subjective, but suffice it to say that it may take some users a short period of time to get used to the difference. In addition, because there is no discernable background noise or "static" in a digital system, if a user keys his or her radio but does not speak, other users may not know the channel is actually in use because it will remain silent. In addition, there is no "squelch tail" with digital systems as there often is with analog repeaters.

Unlike analog systems, there generally is not a gradual degradation in service quality when approaching the edge of coverage with a digital P25 system. Similar to digital cellular telephones, coverage/audio quality is usually very good until hitting a sharp drop off to very poor service or even out of range. Digital systems such as P25 are often able to maintain high quality audio at greater distances from radio sites than comparable analog systems, which can result in users experiencing "better" overall coverage.

An important downside of P25 to consider, particularly in mountainous environments such as those found in southern Gallatin County, is its susceptibility to *multipath* and other types of interference. Because reliable decoding of the digital signal is required to recover the transmitted audio, any corruption of the signal can result in garbled audio or no audio whatsoever. Multipath interference, often resulting from signals reflecting off of hills, canyon walls, or even multiple simulcast transmitters, can be highly destructive to P25 signals. Although analog signals are affected by such interference as well, it is often still possible to understand the message being transmitted through the distortion.

Other Considerations

P25 radios are more expensive than comparable analog-only radios. Many grants, however, require the purchase of P25-capable radios. While this may not be an issue for radios purchased under a grant, if additional radios are needed at some point in the future and grant funding is not available, it may cost significantly more to purchase the same model(s) of P25 radio than it would have for comparable analog-only radios.

Currently in Gallatin County, only the trunked "state" system operates in P25 mode. This system is not generally used for day-to-day dispatch operations for Gallatin County users, however.

If a trunked system or use of encryption is desired, P25 digital (either Phase 1 or Phase 2) would be the most appropriate technology for Gallatin County.

DMR

Digital mobile radio (DMR) is an open digital radio standard specified for professional mobile radio users developed by the European Telecommunications Standards Institute (ETSI) and is used throughout the world. The standard was originally ratified in 2005. DMR was designed as a low-cost, entry level radio system for commercial use. It is typically targeted at the professional industrial and business markets and was not designed for mission-critical communications such as public safety. DMR is available for conventional operation ("Tier II") as well as for trunked operation ("Tier III").[5]

DMR uses a 6.25 kHz-equivalent narrowband compliant two-slot TDMA air interface (12.5 kHz per channel), ***but it is not compatible with P25***. DMR systems are intended to have low complexity, low cost, and offer competition between radio manufacturers, facilitated by the open standard. DMR also offers advanced capabilities such as location-based (GPS) tracking, text messaging, and allows for third-party development of other applications. As with P25, however, some manufacturers have added proprietary "features" that may be incompatible with other vendors' radios.

DMR systems typically do not offer the redundancy or other important features that are available with public safety-grade systems such as P25. For instance, the primary DMR suppliers do not offer simulcast capability. Also, the ETSI standard does not itself support encryption, although some vendors have implemented encryption using standard algorithms. DMR portable and mobile radios are not normally designed to have the same survivability (e.g., hardening, waterproof) and ergonomics as many public safety radios. Further, options such as noise canceling microphones are not typically available, which can be critical for life-safety operations in high-noise environments.

Because it was not designed for mission-critical public safety communications, **ADCOMM does not recommend Gallatin County consider DMR for its radio system upgrade.**

Backhaul Options

An important consideration for an LMR system is the connectivity between remote radio sites and the dispatch center. Various backhaul technologies are available, each having its own distinct advantages and disadvantages, and are described in this section. Importantly, the type(s) of backhaul employed can have an impact on the overall reliability of the system. Depending on what makes most sense for the individual radio sites, it is possible that a combination of backhaul methods could be used for the upgraded Gallatin County radio system.

Leased Lines

Leased lines, sometimes referred to simply as *copper*, *telco circuit*, *phone line*, or T1, are dedicated communication circuits typically provided by a landline telephone company used for connecting remote radio sites to a centralized location, often a dispatch center. Such circuits are avail-

[5] One of the most popular DMR products in the United States is Motorola's *MOTOTRBO™* product.

able with different capacities. Leased lines are not always available at remote mountaintop sites, however.

The primary advantage of using leased lines is that they often have low up-front costs and can often be installed in a relatively short period of time. However, the ongoing costs, depending primarily on line distance and capacity, can be high. In addition, leased line reliability is not always adequate for mission-critical communication systems. The maintenance and repair of such lines is out of the control of the customer; the service provider must be relied upon to restore outages. In addition, leased lines are not always suitable for implementing simulcast technology.

Licensed Microwave

FCC-licensed private point-to-point microwave systems can provide highly reliable, high-bandwidth connections to remote radio sites. The most common microwave bands include 6 GHz, 11 GHz, and 18 GHz. Gallatin County currently also operates some 23 GHz links. Microwave systems require line-of-sight between path endpoints, which can pose significant challenges in some areas, particularly in southern Gallatin County. In addition, microwave paths are distance-limited, with higher frequencies being limited to shorter paths. Further, higher frequency microwave paths, including those at 18 and 23 GHz, can be negatively impacted by rain and snow, causing outages or reduced performance.

Licensed microwave has the advantage that it is controlled entirely by the licensee and is afforded interference protection from other microwave users. Reliance on a third party is not necessary for repairs and maintenance. In addition, with proper system design, such as use of loop protection and/or *monitored hot-standby* (MHSB), license microwave can provide robust redundancy in the event of a partial system outage. The stability of microwave makes it a good choice to use with a simulcast system. Since microwave radios operate continuously, their use at alternative-power (e.g., solar) sites can be challenging due to their power supply requirements.

Upfront costs can be high for licensed microwave equipment. However, ongoing costs are minimal, and it may even be possible to generate revenue from spare capacity or trade for other services.

Unlicensed Microwave

Unlicensed microwave, while similar in many respects to *licensed* microwave, does not afford any interference protection from other users. As a result, its reliability is impossible to guarantee, especially since the interference environment can change over time. Many unlicensed microwave bands, including 2.4 GHz and 5.8 GHz, are shared with consumer devices such as wireless routers, cordless phones, and even Bluetooth devices.

Although unlicensed microwave equipment can be less expensive than licensed equipment and there is not any coordination or licensing costs, its use is not generally recommended for mission-critical communication systems.

Fiber

Fiber optic cables are able to provide high-capacity communications connectivity over both short and long distances. The chief impediment to using fiber is its installation, which can be cumbersome and expensive, particularly when installed underground. Where it is already in place, fiber can be a good option for connecting radio sites and dispatch centers. However, it may not be practical to install new fiber to remote mountaintop radio sites. The stability and bandwidth capacity of fiber make it suitable for simulcast operations.

Fiber connections are generally reliable; however, unlike microwave they are subject to "back-hoe fades," where an underground cable is inadvertently cut by digging. Such cuts can take many hours (or longer) to repair. In addition, fiber cables and telephone lines installed above ground can be susceptible to natural and manmade disasters such as fires.

RF Links

Point-to-point RF links, using radios in non-microwave frequency bands such as VHF or UHF, can be used for connectivity to remote radio sites. Such links are relatively low capacity compared to microwave and fiber since a separate link is needed for each remote base station or repeater. Although RF links can potentially be operated over long distances, frequency availability can make this difficult in some areas. The additional equipment associated with an RF link also increases the number of failure points in the system.

In areas where phone lines and fiber are not available and microwave is impractical, RF links can be a low capacity yet effective, moderate-cost alternative.

RF Control Stations

The least desirable method of controlling remote repeaters is the use of RF *control stations*. These are essentially mobile radios configured to access the radio system as any other subscriber would by simply transmitting on a repeater's receive/input frequency and listening on the repeater's transmit/output frequency (control stations cannot be used to access simplex base stations). Because they simply act as another subscriber radio, control stations do not offer *console priority* capability, whereby a dispatcher can override another user on the system, as may be necessary in the event of a stuck field user's microphone. Leased lines, microwave, fiber, and RF links generally do offer console priority.

Control stations are relatively inexpensive to implement, although in some cases it may be necessary to install them at a remote location that is able to access the necessary repeater(s). Such is the case with the existing control station at Big Sky, which is used to access the Andesite and Eaglehead south repeaters. Depending on how they are implemented, control stations can increase system complexity and the number of failure points.

Other Technology Considerations

In addition to the primary system technology options detailed above, some additional options and technologies worth noting are included in this section.

Shared-Use Channels

In the case of a conventional system (as opposed to a trunked system), because of the limited availability of new frequencies, the deployment of *shared-use* channels would improve radio resource efficiency, in particular for tactical and/or on-demand needs. For example, today in southern Gallatin County, the primary dispatch channel is a shared-use channel, used by both fire/EMS and law enforcement. While perhaps not always ideal, shared-use channels can be beneficial in some instances since it facilitates straightforward interoperability between agencies that are all using a common radio channel.

Vehicular Repeaters

A *vehicular repeater* is a device installed in a vehicle and connected to a mobile radio that acts as a repeater for a relatively small area around the vehicle, allowing one or more nearby users to use portable radios to "talk through" to another radio channel. This allows use of portable radios in areas where only mobile coverage is available.

Vehicular repeaters can be operated in a *cross-band* configuration, whereby a portable radio on one frequency band (e.g., UHF) is used to talk through to a channel on another frequency band (e.g., VHF). This configuration simplifies the necessary in-vehicle equipment configuration. It is also sometimes possible to operate an *in-band* vehicular repeater, whereby the portable radio and mobile radio operate in the same band (e.g., both VHF). This configuration normally requires additional equipment, such as filters, to be installed in the vehicle. There may also be restrictions on which channels can be accessed due to frequency separation requirements of the repeater. If a cross-band configuration is used, portable radios would of course need to be capable of operating in the associated frequency band (e.g., UHF in the aforementioned example).

Regardless of the band configuration, caution should be taken with the use of vehicular repeaters. Interference and device conflicts can occur when more than one vehicular repeater is enabled in the same vicinity. Manufacturers have implemented algorithms to mitigate such problems; however, conflicts might still occur, so their use should be coordinated and users be made aware that conflicts can occur. The devices should be disabled or powered off when not in use.

In cases where portable coverage is needed but only mobile coverage is available, ADCOMM believes limited use of vehicular repeaters, particularly in less populated areas, could be beneficial in Gallatin County.

FirstNet

FirstNet is an independent authority within the National Telecommunications and Information Administration (NTIA) of the Federal Government, created under the Middle Class Tax Relief and Job Creation Act of 2012. The purpose of FirstNet is to establish, operate, and maintain a nationwide interoperable public safety broadband communications network. To fulfill these objectives, Congress allotted $7 billion and 20 MHz of radio spectrum in the 700 MHz band to build the network. It is widely recognized, however, that significant additional funding, with varying estimates between $10 billion and $50+ billion, will be needed to fully construct the network.

The FirstNet network is intended to be a standards-based *Long-Term Evolution* (LTE) network—the same technology employed in many commercial "4G" cellular networks. Initially, the LTE network will provide wireless data service only; there will be no standards-based voice or push-to-talk capability. The vision, however, is to eventually be able to support push-to-talk and other voice traffic, using technology such as *Voice over LTE* (VoLTE). FirstNet is essentially a public safety cellular system that would provide similar coverage as commercial cellular systems provide.

Except for some very small initial build-outs around the country, the FirstNet system does not exist today. If successful, it will take many years and significant additional funding to fully construct the network. Due to efficiencies of scale and usage demand, it is anticipated that the network will first be constructed in larger cities, followed by smaller cities and eventually rural areas.

Because of the lack of funding certainty and anticipated construction timeframes, ADCOMM does not believe FirstNet will be available in Gallatin County any time in the foreseeable future.

Summary

Although there are a variety of LMR technology options available, ADCOMM believes there are two primary options worth considering for Gallatin County.

Given the relatively small number of channels needed in Gallatin County, it is not believed that the expense and complexity of a trunked system is warranted. As such, a multi-channel, conventional simulcast system is believed to be most appropriate as the foundation for Gallatin County's updated radio system, perhaps augmented with some combination of standalone repeaters, transmitter steering, and/or multicast to cover outlying areas. A move to simulcast would provide significantly improved coverage for users as well as simplified operation for both field users and dispatchers alike.

One of the two primary options would be to continue to use VHF for the new system, which would allow many of the existing subscriber radios to be reused, at least for analog operation. If P25 is used instead, at least some subscriber radios would need to be upgraded or replaced. In addition, the limited availability of additional VHF frequencies may impact the number of channels that could actually be deployed.

The second alternative, primarily to overcome the limited availability of VHF frequencies, would be to deploy the new system at UHF, which has more available frequencies in Gallatin County. Unfortunately, a move to UHF would require the purchase of all new mobile and portable radios, significantly increasing overall project costs.

Final Report

Gallatin County 9-1-1 Radio System Engineering Study High-Level Radio System Design and Strategic Directions

Prepared for
Gallatin County 9-1-1

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Date Prepared
July 20, 2015

ADCOMM Engineering Company
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Acronyms and Abbreviations

ADCOMM	ADCOMM Engineering Company
BDH	Bozeman Deaconess Hospital
EMS	emergency medical services
EOC	Gallatin County Emergency Operations Center
ERP	effective radiated power
FCC	Federal Communications Commission
Gallatin 9-1-1	Gallatin County 9-1-1
GPS	global positioning system
IP	Internet Protocol
MHz	megahertz
MHSB	monitored hot-standby
MSU	Montana State University
OTAP	over-the-air programming
OTAR	over-the-air rekeying
P25	APCO Project 25
RF	radio frequency
UHF	ultra high frequency
VHF	very high frequency
WSCA	Western States Contracting Alliance

High-Level Radio System Design

Executive Summary

This report describes a radio system option based on the current state report, user input, technology review, and radio coverage analysis. The final recommendation is for a new radio system using UHF frequencies in the Gallatin Valley and Bozeman areas, VHF frequencies in the extreme north and south areas, and a mix of standalone, simulcast, and multicast technologies chosen to optimize the system performance at the lowest cost for each type of terrain and use. The system would be a mix of Project 25 digital technologies and narrowband analog depending on what is appropriate for the terrain and use. The estimated total system cost is approximately $21,000,000.

The level of detail in this phase of the project was defined by the project scope to be adequate to define a budget and to define the system for future detailed design efforts when the Gallatin County public safety users decide to move forward with funding.

Introduction

Project Purpose and Scope

In February 2014, ADCOMM was contracted by Gallatin County 9-1-1 to perform a radio system study. In general, the purpose of this project was to determine the state of the existing public safety two-way radio communication systems in use by stakeholders in the county, identify the operational needs of the radio systems' users, identify potential technologies and their applicability to a replacement/upgraded radio system, and develop a high-level system design for such a system, followed by solution selection and implementation preparation.

Based on this contract, the project consists of the following phases:

1. **Phase One: Information Gathering and Education.** The deliverables of Phase One are the Current State Report, the User Needs and Gap Analysis, and the Technology Review. The purpose of this phase is to generate information needed by ADCOMM and by stakeholders to fully understand the existing systems, both for comparison purposes and to identify the needs of the systems' users.

2. **Phase Two: Solution Development.** Using the information gathered during Phase One, Solution Development's deliverable is a list of potential solutions, with rough order of magnitude costs, to the challenges faced by Gallatin County's radio systems. The end of Phase Two is a joint meeting to discuss and evaluate each of the potential solutions, with the County deciding on one or more potential solutions for further development. Selection of the solution at this stage begins to set the strategic direction.

3. **Phase Three: Strategic Direction and High-Level Design.** During Phase Three, the selected solution is developed further to yield a strategic direction document and a high-level design ***(this report)***. The solution will be divided into a series of implementable modules, with estimated costs, implementation time, and impact to the voice systems identified. The High-Level Design will be sufficient to drive the detailed engineering needed as the first step toward acquisition and implementation.

4. **Phase Four: Final Study Report.** The Final Study Report is a combination of all the deliverables created in the project with a summary and explanatory text for use in grant justifications and budget discussions. ADCOMM anticipates an in-person delivery of the final report to Gallatin County decision makers and stakeholders at a combined meeting.

5. **Phase Five: Solution Selection and Implementation Preparation.** Following the Final Study Report release, stakeholders will meet to identify specific solutions for implementation. These solutions will be further developed to produce engineering drawings, detailed system price estimates, and technical specifications for use in procurement and implementation. Solution development will be for voice radio system changes only.

Note that the following are not included in the scope of work for the current project: technical procurement reviews and assistance, vendor selection, technical support during contract negotiations, implementation engineering services, and/or project management.

High-Level Radio System Design

Following the earlier project phases, the High-Level Radio System Design describes the county's ultimate radio system, or the desired end-state. The High-Level Design is not a fully engineered solution but rather a guiding document for the full set of engineering documents needed for procurement and implementation. The High-Level Design includes the following elements:

1. Recommended radio sites
2. Transport recommendations, as applicable
3. Composite and individual coverage maps for each radio site
4. Overall channel plan and per-site channel plan, as applicable

The direction taken for the High-Level Design was based on the identified user needs, system requirements, available technology options, and feedback from the project stakeholders. This was done over a series of meetings with the stakeholders describing the technology, system options, and the final consensus approach.

Recommended Voice Radio System

Based on the technology options identified in the Technology Review report, in conjunction with the identified needs of the users and feedback provided by project stakeholders, ADCOMM recommends the following for Gallatin County's upgraded public safety radio system:

1. Continue operation of all systems in *conventional* (non-trunked) mode, appropriate for the relatively small number of channels needed.

2. Deploy a three-channel *simulcast and voted-receive* system for **City of Bozeman** police, fire, and EMS users, consisting of three simulcast transmit sites and nine voted-receive sites. Under normal circumstances, one channel would be used for Bozeman Fire/EMS, one for Bozeman PD, and one for use as needed (see Figure 1, "Bozeman Simulcast").

3. Deploy a three-channel *simulcast and voted-receive* system for **north county** law enforcement, fire, and EMS users (generally non-Bozeman), providing coverage north of the Gallatin Range and consisting of 10 simulcast transmit sites and 15 voted-receive sites. Under normal

circumstances, one channel would be used for Fire/EMS, one for law enforcement (including GCSO and Belgrade PD), and one for use as needed (see Figure 2, "North Simulcast").

4. Deploy one shared-use *multicast and voted-receive* channel for **south county** law enforcement, fire, and EMS users, providing coverage generally between Spanish Creek Road and West Yellowstone, including Big Sky, consisting of five transmit sites and six voted-receive sites (see Figure 3, "South Multicast").
5. Deploy one standalone repeater at Hyalite Canyon for shared-use by law enforcement, fire, and EMS users ("Hyalite").
6. Deploy one standalone repeater in the vicinity of Hatfield Mountain for shared-use by law enforcement, fire, and EMS users in the extreme north portions of the county ("Hatfield").
7. Deploy the Bozeman, North, Hyalite, and Hatfield systems using Project 25 (P25) Phase 1 digital technology to facilitate encrypted-voice capability and provide improved coverage relative to narrowband analog.
8. Deploy the South system using analog FM technology to maintain straightforward interoperability with other agencies in the Canyon/Big Sky/Yellowstone areas and to avoid some of the coverage problems associated P25 digital in canyons due to multipath.
9. Deploy the Bozeman and North systems using UHF frequencies (450 to 470 MHz) to take advantage of the lower RF noise environment in this band, improved simulcast optimization control, and to allow for a sufficient number of channels to be licensed.
10. Deploy the South system using VHF frequencies to maintain straightforward interoperability with other agencies in the Canyon/Big Sky/Yellowstone areas and to take advantage of the improved non-line-of-sight coverage of VHF frequencies compared to UHF.
11. Deploy the Hyalite and Hatfield standalone repeaters using VHF frequencies, if possible, to maximize coverage in the rural (and relatively low RF noise) areas served by these sites.
12. Replace other existing standalone repeaters (e.g., fire tactical, search-and-rescue, etc.), and deploy additional as necessary, with stations that will continue to be manufacturer-supported for the foreseeable future, using existing frequencies.
13. Deploy licensed microwave links using IP-based technology to all new sites, as possible. For low capacity and/or alternative-power sites, use of UHF links may be sufficient in place of microwave.
14. Deploy dual-band (VHF-UHF) user radios to accommodate the dual-band nature of the radio system infrastructure.

Because many of the new systems are proposed to be deployed in the UHF frequency band, which is not currently used by most Gallatin County users, new subscriber radios (mobiles and portables) that are capable of operation on these frequencies will be needed for most agencies. Further, since many areas will continue to employ VHF infrastructure, and to maintain interoperability with surrounding mutual aid agencies, dual-band radios will be essential in many circumstances.

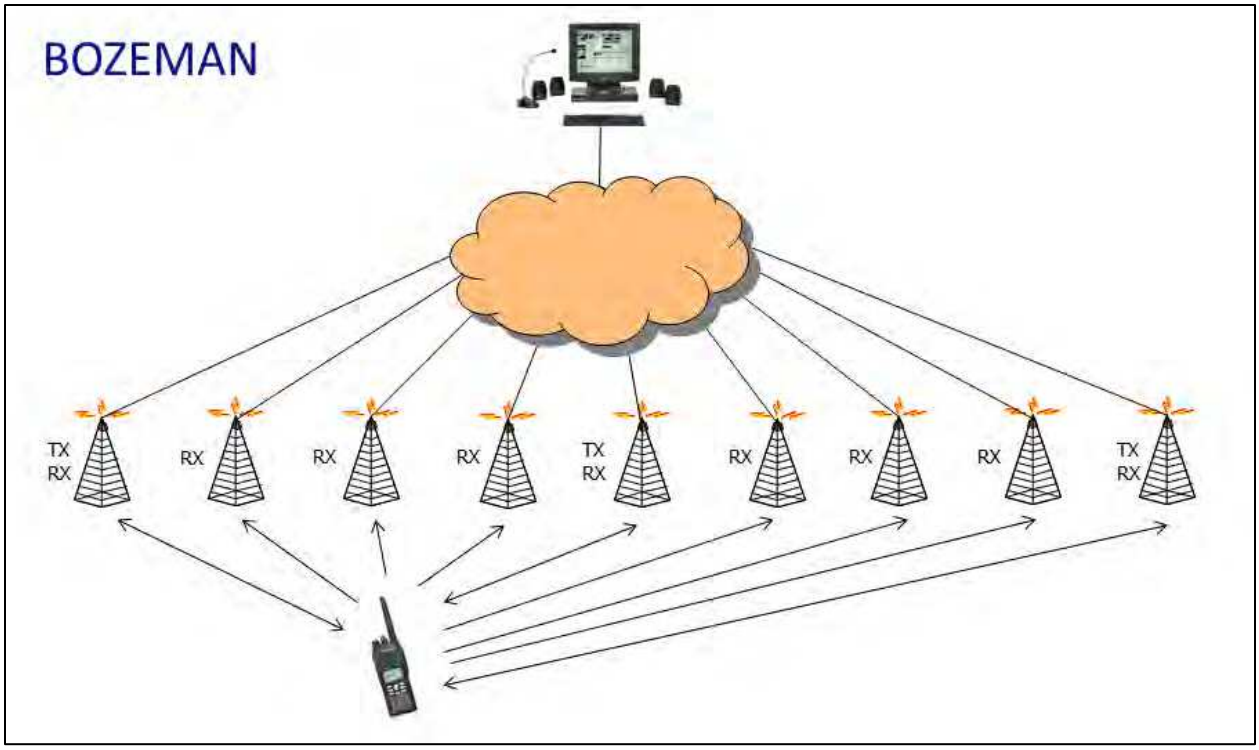


FIGURE 1
Proposed Nine-Site Bozeman Simulcast/Voted System Configuration (one of three channels)

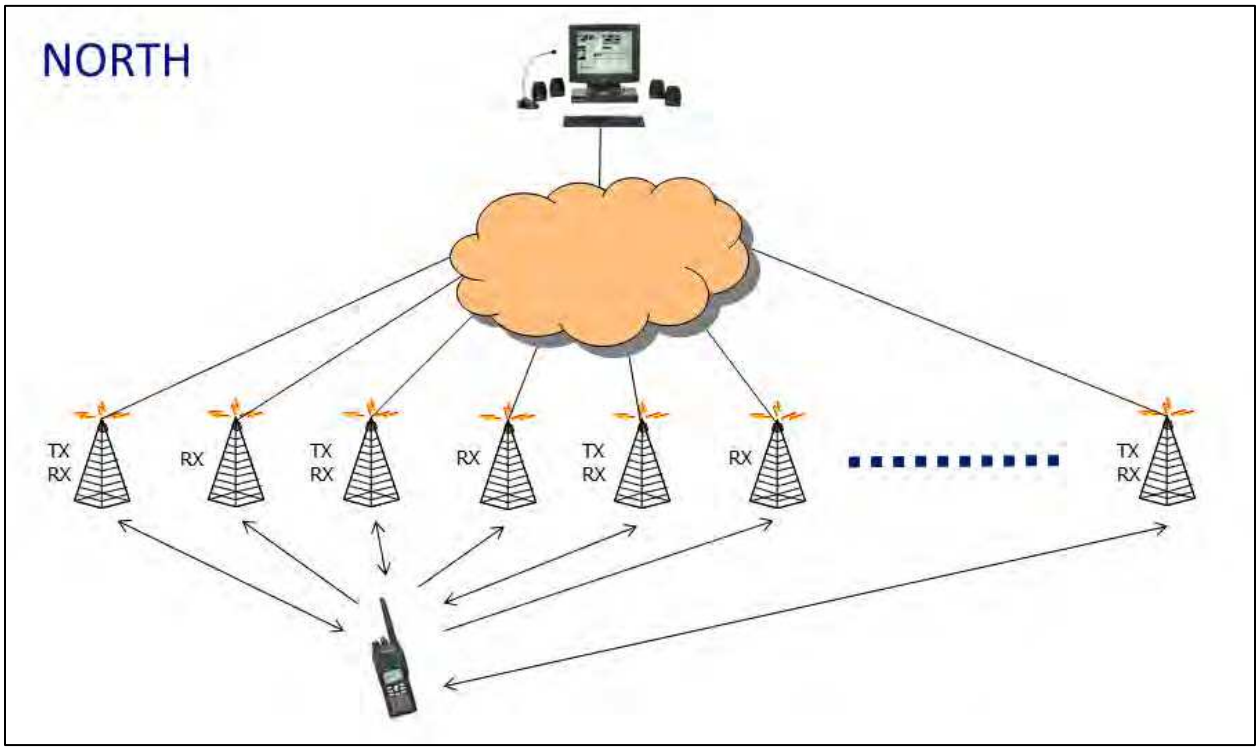


FIGURE 2
Proposed 15-Site North Simulcast/Voted System Configuration (one of three channels)

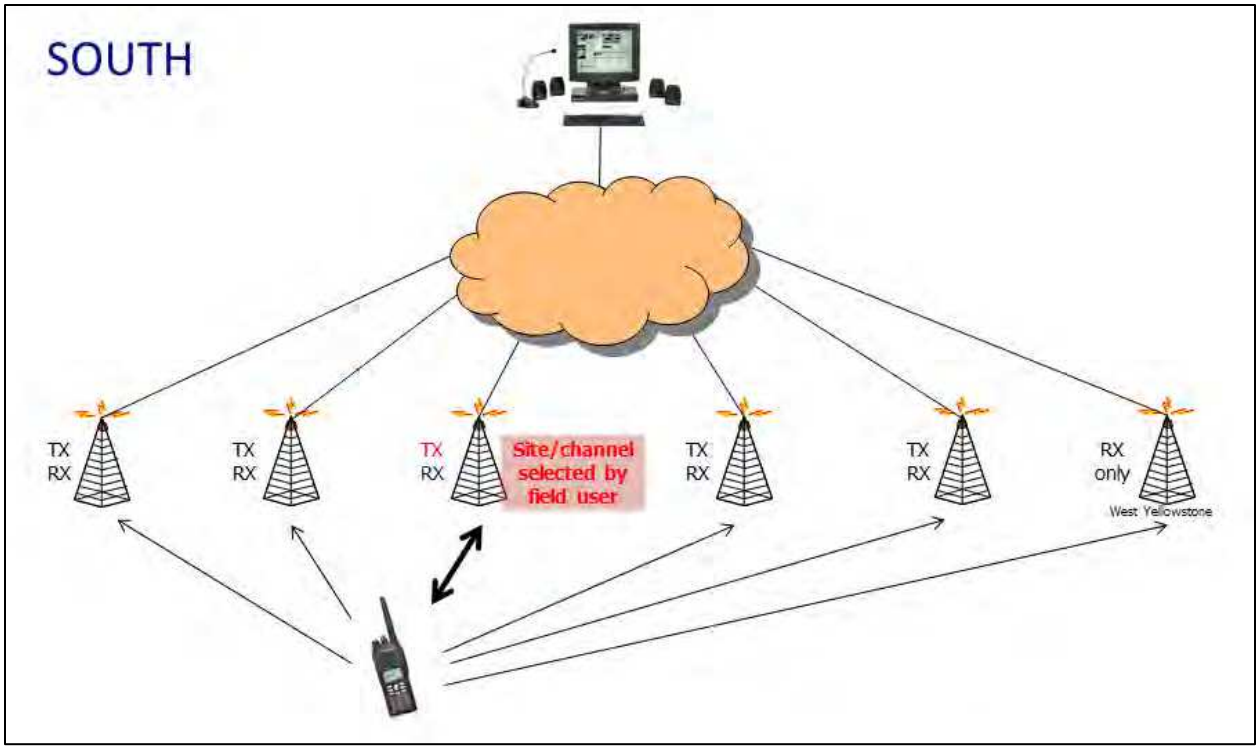


FIGURE 3
Proposed Six-Site South Multicast/Voted System Configuration

Proposed Sites

To leverage existing assets and favorable site agreements, ADCOMM recommends deploying the proposed radio systems using existing Gallatin County radio sites to the extent possible. However, in some cases, additional or relocated sites are recommended. The following sites are recommended for the proposed radio system.

1. 9-1-1 Center
   45° 41′ 43.2″ N, 111° 05′ 01.4″ W[1]
2. Belgrade Water Tower
   45° 46′ 24.3″ N, 111° 10′ 07.0″ W
3. Big Sky Resort
   45° 16′ 24.7″ N, 111° 23′ 41.1″ W
4. Bozeman Deaconess Hospital (BDH), new building
   45° 40′ 06.3″ N, 111° 01′ 24.9″ W
5. Bozeman High School
   45° 40′ 57.5″ N, 111° 03′ 11.5″ W
6. Bridger Ridge
   45° 49′ 00.6″ N, 110° 55′ 47.0″ W

[1] All listed site coordinates at NAD83.

7. Bridger Woods / Green Mountain
   45° 41′ 48.3″ N, 110° 53′ 22.3″ W
8. Cinnamon Mountain
   45° 07′ 48.5″ N, 111° 16′ 06.8″ W
9. Cobleigh Hall (MSU)
   45° 39′ 59.6″ N, 111° 02′ 45.6″ W
10. Eaglehead
    45° 13′ 26.0″ N, 111° 07′ 23.2″ W
11. Four Corners (fire station)
    45° 40′ 32.6″ N, 111° 11′ 28.4″ W
12. Gallatin County Courthouse
    45° 40′ 46.7″ N, 111° 02′ 30.4″ W
13. Gallatin County Emergency Operations Center (EOC)
    45° 41′ 20.2″ N, 111° 01′ 59.0″ W
14. Garnet Mountain
    45° 25′ 35.6″ N, 111° 12′ 24.4″ W
15. Hatfield Mountain
    46° 05′ 24.2″ N, 110° 58′ 31.7″ W
16. High Flats
    45° 38′ 15.9″ N, 111° 16′ 04.7″ W
17. Horse Butte
    44° 45′ 04.0″ N, 111° 11′ 45.1″ W
18. Hyalite Canyon
    45° 26′ 47.7″ N, 110° 56′ 33.3″ W
19. Kenyon Water Tower
    45° 39′ 42.3″ N, 111° 01′ 31.6″ W
20. Law and Justice Center
    45° 40′ 24.9″ N, 111° 03′ 32.4″ W
21. Lombard/Toston
    46° 07′ 00.6″ N, 111° 22′ 51.5″ W
22. Madison River (Montana Rail Link)
    45° 46′ 03.7″ N, 111° 34′ 44.8″ W
23. Manhattan (Little Apple Technologies)
    45° 51′ 22.0″ N, 111° 20′ 03.2″ W
24. Nixon Ridge
    45° 57′ 55.7″ N, 111° 20′ 18.9″ W
25. Three Forks (American Tower)
    45° 52′ 38.5″ N, 111° 32′ 04.6″ W

26. Timberline
    45° 39′ 31.7″ N, 110° 48′ 25.0″ W
27. West Bozeman (Crown Castle)
    45° 40′ 23.3″ N, 111° 06′ 22.8″ W
28. West Yellowstone (fire station)
    44° 39′ 30.4″ N, 111° 06′ 24.0″ W
29. Willow Creek (fire station)
    45° 49′ 38.1″ N, 111° 38′ 43.2″ W

In addition to the remote radio sites and equipment, simulcast control and voting equipment will be needed for the various systems. Depending on the particular vendor chosen, it is anticipated that this equipment will generally consist of several racks of equipment. It is recommended that this equipment be installed at a readily accessible location, such as the 9-1-1 center, for maintenance purposes.

Channel Plan

Each of the proposed simulcast, multicast, and standalone subsystems will use different radio sites to provide the necessary coverage. The sites anticipated to be included for each subsystem are detailed in this section.

Bozeman Simulcast (three channels)

Transmit and Receive Sites

1. 9-1-1 Center
2. EOC
3. Kenyon Water Tower

Receive-only Sites

1. Bozeman Deaconess Hospital
2. Bozeman High School
3. Cobleigh Hall (MSU)
4. Courthouse
5. Law and Justice Center
6. West Bozeman

North Simulcast (three channels)

Transmit and Receive Sites

1. 9-1-1 Center
2. Belgrade Water Tower
3. Bridger Ridge
4. Bridger Woods/Green Mountain
5. High Flats
6. Kenyon Water Tower
7. Lombard/Toston
8. Madison River
9. Nixon Ridge
10. Timberline

Receive-only Sites

1. Four Corners
2. Law and Justice Center
3. Manhattan
4. Three Forks
5. Willow Creek

South Multicast (one channel)

Transmit and Receive Sites

1. Big Sky Resort
2. Cinnamon Mountain
3. Eaglehead
4. Garnet Mountain
5. Horse Butte

Receive-only Sites

1. West Yellowstone

Hyalite Canyon Standalone (one channel)

Transmit and Receive Sites

1. Hyalite Canyon

Hatfield Mountain Standalone (one channel)

Transmit and Receive Sites

1. Hatfield Mountain

Table 1 summarizes the proposed channel plan by site and channel, indicating how many transmitters and receivers are needed for each.

Coverage Predictions

Composite computer-generated coverage predictions for the proposed Gallatin County radio system can be found in Appendix A. Individual-site coverage predictions can be found in Appendix B. The Longley-Rice propagation model was used to make the computations. Composite "talk-out" (that is, from the fixed radio sites—including dispatch—to field units) and "talk-in" (from field units into the system) plots are included for each proposed subsystem. The predictions did not take into account any ambient interference from other radio systems or man-made obstacles in the desired service areas, as these can be highly variable.

It is important to note that there are limitations to the accuracy of computer-generated coverage predictions due to resolution and accuracy limitations of the terrain and land-use ("clutter") databases employed, along with multipath factors, propagation conditions, and other approximations inherent with the propagation model employed. As such, caution should be used when interpreting the accuracy of the predictions. Specific points on any particular prediction map might not accurately reflect the actual signal at those locations. That said, coverage predictions can provide a good general indication of coverage across an area.

TABLE 1
Channel Plan by Site

Disptach Channels →	Bozeman Simulcast (UHF)		North Simulcast (UHF)		South Multicast (VHF)		Standalone-Dispatch (VHF)		Standalone-Tac, other (VHF or UHF)		**Total**	**Total**
Site ↓	TX	RX	TX	RX	TX	RX	TX	RX	TX	RX	**TX**	**RX**
9-1-1 Center	3	3	3	3							**6**	**6**
Belgrade			3	3							**3**	**3**
Big Sky Resort					1	1			1	1	**2**	**2**
Bozeman Deaconess Hosp.		3							1	1	**1**	**4**
Bozeman HS		3									**0**	**3**
Bridger Ridge			3	3							**3**	**3**
Bridger Woods/Green Mt			3	3							**3**	**3**
Cinnamon Mt					1	1					**1**	**1**
Cobleigh Hall (MSU)		3									**0**	**3**
Courthouse		3									**0**	**3**
Eaglehead					1	1					**1**	**1**
EOC	3	3									**3**	**3**
Four Corners				3							**0**	**3**
Garnet Mt					1	1					**1**	**1**
Hatfield Mt							1	1			**1**	**1**
High Flats			3	3							**3**	**3**
Horse Butte					1	1					**1**	**1**
Hyalite Canyon							1	1			**1**	**1**
Kenyon W.T.	3	3	3	3							**6**	**6**
Law & Justice Center		3		3							**0**	**6**
Lombard/Toston			3	3							**3**	**3**
Madison River			3	3							**3**	**3**
Manhattan				3							**0**	**3**
Nixon Ridge			3	3					1	1	**4**	**4**
Three Forks				3							**0**	**3**
Timberline			3	3					1	1	**4**	**4**
West Bozeman		3									**0**	**3**
West Yellowstone						1					**0**	**1**
Willow Creek				3							**0**	**3**
Other - locations TBD									8	8	**8**	**8**
	TX	RX	TX	RX	TX	RX	TX	RX	TX	RX	**TX**	**RX**
Total stations	9	27	30	45	5	6	2	2	12	12	**58**	**92**
Total sites	3	9	10	15	5	6	2	2	12	12	**19**	**29**

The maps in Appendix A and Appendix B illustrate where mobile and various levels of portable on-belt coverage are predicted to be available today with 95 percent reliability, using assumed parameters, including:

- 100 watts effective radiated power (ERP)[2] or the currently authorized ERP, whichever is lower, for each station
- Directional or omnidirectional transmit antennas to mitigate simulcast overlap interference as necessary
- Omnidirectional receive antennas

Areas in blue indicate mobile coverage for a 50-watt mobile station, and areas in green, yellow, and red indicate various levels of portable coverage for a 5-watt portable radio worn on-belt.

[2] Effective radiated power takes into consideration the transmitter output power along with antenna system gains and losses, such as transmission line and connector losses, combiner loss, and antenna gain.

Backhaul

The proposed radio system will require robust digital connectivity between the various remote radio sites, simulcast control equipment, and dispatch center. It is also recommended that redundant connectivity configurations be used. This can be accomplished with redundant equipment as discussed below.

Loop Configuration

In a loop configuration, all of the sites in the loop are connected together in such a way that the sites have two connections back to the primary site (see Figure 4).

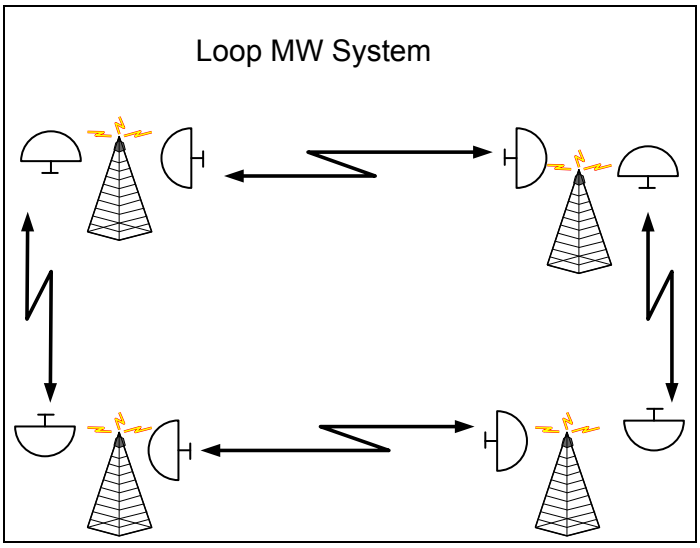


FIGURE 4
Loop Microwave System

One of the significant advantages with this approach is that even the loss of one of the antennas at a site will not result in the loss of connectivity. There is additional protection from path fading as well since it is unlikely that both paths into a site will fade at the same time. The biggest drawback to a loop system is the additional cost for the antennas and loop switching equipment. Note that the loop protection can be provided by other technologies such as fiber. If fiber is available between two locations, the fiber could be used in lieu of microwave.

Monitored Hot-Standby (MHSB)

Monitored hot-standby systems have electronic equipment redundancy but do not have antenna redundancy. If the antenna is damaged, the connection to the site may be lost. In addition, if the path fades, the connection to the site may also be lost. MHSB equipment is often used at locations where it is not feasible to get another path into a site. For example, a site may be located in a valley or on the side of a mountain where there are not two locations that have a clear view of the site. A typical system diagram is shown in Figure 5.

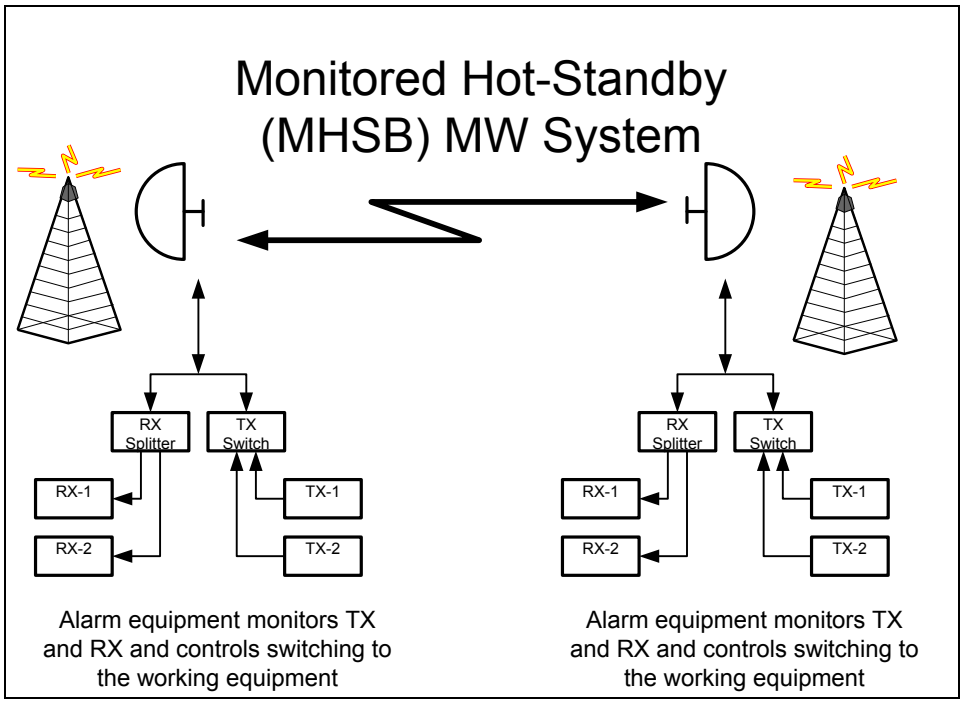


FIGURE 5
MHSB Microwave System

Many systems use a mix of loop and MHSB technologies. It is anticipated the Gallatin County system would use a mix of these two technologies depending on the final design.

Wherever possible, it is recommended that licensed microwave be deployed where fiber or existing microwave is not available. The frequency band for each microwave hop will depend on the final overall microwave/backhaul plan, including system layout, path lengths, required link capacities, and frequency availability. In order to maximize capacity, operational flexibility, and manufacturer support, it is recommended that all backhaul systems be *Internet Protocol* (IP)-based.

Budgetary Costs

Table 2 identifies a high-level breakdown of estimated capital costs for the proposed radio system upgrades. Ongoing system maintenance and operational costs are not included.

Table 3 identifies estimated unit costs for various tiers of subscriber equipment. The high tier is for dual-band (e.g., VHF and UHF) equipment, while the low and medium tiers are for single-band (i.e., UHF only) equipment. Installation, setup, and a normal mix of accessories are included in the Table 2 cost estimates. The high-tier and medium-tier equipment include advanced features[3] such as encryption, over-the-air rekeying (OTAR), over-the-air programming (OTAP), and GPS, while the low-tier equipment does not include any such advanced features.

[3] Note that some advanced features may be vendor-proprietary, not P25 standards-based.

TABLE 2
Radio System Upgrade Capital Cost Estimate Summary

Item	Estimated Cost
VHF/UHF radio infrastructure equipment[4] (29 sites)	$3,000,000
Site antenna systems	$1,100,000
Site improvements, new site development (29 sites)	$4,600,000
New subscriber radios, including installation (est. qty. 1,500)	$7,500,000
New consoles (0)	$0
Microwave and networking	$3,400,000
Alphanumeric paging system improvements	$240,000
Equipment installation	$3,000,000
FCC licensing	$140,000
Engineering, project management, consulting	$1,200,000
Sales tax (0%)	$0
Contingency (20%)	$4,800,000
TOTAL	**$28,980,000**[5]

TABLE 3
Estimated Subscriber Radio Costs

Item	Estimated Unit Cost
Mobile, high-tier (dual-band, including enhanced features)	$5,500
Mobile, medium-tier (single-band, including enhanced features)	$4,500
Mobile, low-tier (single-band, no advanced features)	$2,500
Portable, high-tier (dual-band, including enhanced features)	$5,000
Portable, medium-tier (single-band, including enhanced features)	$4,000
Portable, low-tier (single-band, no advanced features)	$2,000

Summary

Based on the identified user needs and consideration of technologies currently available, ADCOMM believes that a hybrid VHF/UHF radio system, operating in a combination of analog and P25 Phase 1 digital modes, in conjunction with simulcast and multicast technologies, would meet the radio communication needs public safety users in Gallatin County while significantly extending the supported lifespan of the system. Such a system would offer significant operational improvements over the existing radio systems, primarily enhanced coverage and increased channel capacity. However, some operational and procedural changes may be required, in particular regarding interoperability with surrounding agencies. In

[4] Includes nine dispatch channels (three Bozeman Simulcast, three North Simulcast, one South Multicast, Hyalite Canyon, and Hatfield Mountain) plus an estimated 11 standalone repeater (e.g., tactical) channels.

[5] Note that budget numbers discussed previously of approximately $21,000,000 did not include user radios.

addition, improvements to the existing alphanumeric paging system are warranted to improve its reliability.

ADCOMM estimates that approximately 29 radio sites would be necessary to provide the desired coverage throughout Gallatin County. The total estimated capital cost for the project is $29.0 million.[6]

[6] This estimate includes the new radio system infrastructure equipment, installation, site improvements, licensed microwave backhaul, replacement subscriber units, FCC licensing, engineering, project management, and 20 percent contingency.

Strategic Communications Plan

It appears that while Gallatin 9-1-1 has made some significant improvements to their radio communications infrastructure over the last 5 years it was done to resolve specific problems and not part of a larger strategic communications plan. This is quite often the case for agencies that are in areas that have significant growth. What worked for them a decade or two ago, no longer works. This includes not only the technology but also the approach to managing and maintaining the network.

The growth in the Gallatin County area has been significant over the last few years with the population nearing or possibly exceeding 100,000 within a year or so. Current annual growth has been in the range of a bit more than 2 percent to over 8 percent. It is not known if these rates will continue. The influence of the university and the living environment will continue to bring in high-tech industries where the location of the industry depends on access to the Internet, a pool of educated talent, and a great living environment. This will continue to put pressure on providing services, including law enforcement, fire, and EMS to a group of citizens that expect these services as opposed to the more traditional rural approach of handling things yourself and only relying on others' services as a last resort.

This growth has already resulted in the existing public safety communications infrastructure being inadequate for the mission of the responders. Rapid growth also complicates the long-term planning process. The systems needed for the future should be planned and implemented today, which means additional demands on the current citizens to fund a system to support the citizens 5 to 10 years down the road. However, the long lead time of making significant capital improvements to the radio system dictate that the planning and implementation process need to start now so the systems can be in place as soon as possible given the current system inadequacy.

Strategic Planning Areas

ADCOMM sees the following areas for which Gallatin 9-1-1 needs to include in a strategic plan related to the radio communications infrastructure.

- Radio infrastructure system
- Interoperability and interface to the State of Montana
- Interface to dispatch technology and equipment
- Radio systems operation and maintenance
- Radio system funding

These will be discussed in additional detail below.

Radio Infrastructure System

The system approach recommended by ADCOMM should provide adequate service for 5 to 8 years. However, this depends on how fast Gallatin 9-1-1 can fund and implement the system. The basic system architecture allows for some expansion should the growth remain high and additional resources are required. However, the needs of Gallatin County will continue to change based on the economic drivers in the county. While it is expected the growth will continue, it is possible but likely not probable that the growth could slow or stop. As a result,

Gallatin 9-1-1 should start working on a strategic plan review and revision in the 2020 time frame looking out the next 5 to 8 years. One reason this is critical is so that capital expenditures for radio system equipment 8 to 10 years from now can take into consideration any changes in the strategic plan.

The current recommended strategic approach is as follows:

- Continue to use conventional technology as opposed to trunking.
- Move the Gallatin Valley area to a UHF system.
- Procure dual-band user radios.
- Provide dispatch and operational wide area channels for both Bozeman and the Gallatin Valley.
- Use VHF in the south end of the county and extreme north end.
- Continue to use alphanumeric paging.
- Implement Project 25 Phase 1 technology in the Gallatin Valley/Bozeman area to support encryption and improved coverage.
- Implement narrowband analog technology in the southern portions of the county where multipath will negatively affect digital communications.
- Implement a backhaul microwave infrastructure that supports digital IP communications for system interconnection where feasible and other appropriate technology in the rural areas. Note that some of the current radio system traffic is supported by the State microwave system. Some of the State's network uses equipment owned by Gallatin 9-1-1. Gallatin 9-1-1 should develop a comprehensive approach to how they will interface and operate with the State's microwave network. At this point, the State's network does not have adequate maintenance resources allocated to it and maintenance and other work can be delayed.

Interoperability and Interface with the State of Montana and Other Users

The majority of the users in rural Montana currently use VHF radio systems. The State of Montana operates a large VHF trunking system that appears to have only been marginally accepted by the rural non-state users. In addition, Gallatin 9-1-1 currently operates Motorola consoles that are connected to the State of Montana system allowing access to both local county-owned resources as well as the State's trunking system.

The maintenance, operation, and upgrades to a trunking radio system represent significant costs and personnel resources. The current state system has much equipment that is no longer manufactured by their system vendor and at some point will need to be replaced. This represents a significant cost. In addition, the system was not designed for the requirements of local responders in terms of coverage or capacity. As a result, ADCOMM does not believe using trunking technology and/or teaming with the State of Montana is in the best interest of Gallatin County public safety responders from both a technology and a cost point of view. Interface to the State trunked radio system can be done through inexpensive control stations instead of the expensive console interface currently being used. This, of course, could change should the state

legislature decide to fully fund a state-wide system that would provide local services. It appears this is not likely.

In addition to the State trunking system, there is extensive use of VHF analog for fire communications throughout the state. The state has developed a "color channel" system where many if not all agencies use these same frequencies and common nomenclature to aid in responding to large fires and other mutual aid incidents. ADCOMM recommends that any system design approach continue to support this concept and system. This is one of the reasons for the use of dual-band radios.

The current recommended strategic approach is as follows:

- Continue to support the VHF Color Channel system widely used in Montana[7]
- Develop a standalone console system approach instead of being tied to the State of Montana radio system
- Provide interface into the State of Montana trunked radio system by control stations
- Keep some VHF narrowband analog tactical repeaters in operation in Gallatin County for VHF mutual aid, which is expected to be primarily fire response but could be other agencies as well

Interface to Dispatch Technology and Equipment

The current dispatch consoles are connected through the State of Montana central radio system controller. This approach makes sense if Gallatin 9-1-1 made extensive use of the State radio network. However, the existing system makes only occasional use of the State radio system with almost all communications being handled locally. The current system configuration requires even local transmissions to travel to the radio system controllers and back. Given that the direction recommended for Gallatin 9-1-1 is to develop their own radio system network, it makes little sense to continue to use the state controllers. The existing console system can be converted to a standalone system with all of the communications remaining in the Gallatin County area.

The current recommended strategic approach is as follows:

- Convert the existing console system to standalone operation or replace it
- Provide control stations to interface to the State P25 trunking system

Radio Systems Operation and Maintenance

Radio system operation and maintenance is critical to the long-term success of the radio communications system. In addition, proper maintenance can maximize the significant investment made in the radio system infrastructure. However, this has become more difficult and expensive for the reasons below:

- Due to the nature of equipment maintenance, vendor radio shops often have less technical skills than in the past
- Many radio system technicians have retired or are getting close to retirement

[7] Mutual Aid and Common Frequencies Manual 2011, Montana Department of Administration.

- Newer technicians are primarily trained in data and computer systems not radio systems
- There are few schools that teach radio system technology
- The test equipment required to maintain a new technology system can costs tens of thousands of dollars. For example, a fully functional radio service monitor can cost $50,000 or more.
- The technology changes faster requiring more training, which is expensive

This has created a significant problem for radio system operators as they invest in new systems and want to keep those systems operating. This problem is exacerbated when an agency is located some distance from a major metropolitan area where there is usually a greater density of radio equipment and customers supporting a more fully staffed radio shop. The situation in Gallatin County is made worse by the fact that the radio system required will be fairly complex and will require ongoing technical support. This support is not just for the radio system but includes microwave, consoles, radio sites, towers, alarm equipment, and user support for programming and operating user radios. It will take dedicated personnel to learn and be able to maintain the system.

There are three basic approaches to providing system management and maintenance:

1. **Vendor Centric Maintenance**
   A vendor centric maintenance approach is where virtually all of the work is contracted out to local vendors and they are responsible for essentially all of the system maintenance but where the management of the maintenance and system is still with Gallatin 9-1-1. Using this approach, there would be a "Technical Systems Manager" who would be essentially a contract manager. The Technical Systems Manager would need to have a basic understanding of the system and be able to troubleshoot at a very high level in order to know which maintenance contractor to call for service. Different maintenance contractors could be used for different aspects of the system. For example, one local radio shop might maintain the radio portion of the system, the microwave vendor might maintain the microwave equipment, another contractor might maintain the generators and DC power systems, etc. This would allow Gallatin 9-1-1 to pick the best contractor for the work. While the maintenance contractors would do the majority of the work, some small maintenance activities and system alarm monitoring would be done by the Technical System Manager. The primary disadvantage with this approach is the lack of control over the person doing the work and their level of expertise. This approach may be less expensive than an approach where Gallatin 9-1-1 uses their own personnel.

2. **Gallatin 9-1-1 Centric Maintenance**
   The Gallatin 9-1-1 centric maintenance approach is where virtually all of the work is done by Gallatin 9-1-1 personnel with some work contracted out to local vendors for specialty items such as generator and HVAC repair Using this approach, there would be a "Technical Systems Manager" who would be the system manager and would manage one or more technical support staff. The Technical Systems Manager would need to have a good understanding of the system and be able to troubleshoot to provide support to the radio maintenance technician. All alarm monitoring and maintenance response would be done by Gallatin 9-1-1 personnel. The primary advantage with this approach is control over the personnel, quality of work, and level of training. The primary disadvantage of this approach is cost.

3. **Managed Services Approach**
   The managed services approach can take several forms. The most common are:

   - The operations and maintenance of the system are contracted out to a third party but the agency retains ownership of the equipment
   - The operations and maintenance of the system are contracted out to a third party who owns and operates the system on behalf of the agency
   - The management of the system maintenance and operations are contracted out to a firm that can supply high-level technical support but the day-to-day repairs are handled by local vendor forces.

Each of these approaches has advantages and disadvantages, however, for a system of the type and size of Gallatin 9-1-1's, it does not appear that managed services would be a cost-effective approach due to the cost (because of the size of the system). However, depending on the technical resources available, a hybrid approach may be warranted.

The current recommended strategic approach is as follows:

Gallatin 9-1-1 should invest in their own technical support staff for their radio infrastructure and supplement their staff with vendor support where required. This would require a technical systems manager and at least one radio technician depending on the support available from the local radio shops. The Technical Systems Manager should be responsible for all of the technical systems operated by Gallatin 9-1-1 including CAD and the telephone system. Contracted services would be used to provide support for systems such as generators and HVAC as well as to provide high-level technical support if required. The Technical Systems Manager should report directly to the Gallatin 9-1-1 Director. The estimated cost for this is:

Salaries, benefits	$300,000
Annual parts budget, repairs, calibration	$50,000
Operating expenses (fuel, etc.)	$10,000
Annual training	$10,000
Annual contracted services	$100,000
Estimated Annual Cost	**$470,000**
Initial capital expense	$250,000

Radio System Funding

The radio system infrastructure needs both a source of capital funding and ongoing funds. Long gone are the days of paying a few thousand dollars to put a repeater on a mountain top and then not doing anything with it for 20 to 30 years as was often the case in many systems.

Gallatin 9-1-1 is currently designed to operate with funding from a voter approved "mill levy" property tax. This provides the bulk of the Gallatin 9-1-1 operating and maintenance funds with some funding available for improvements. However, the approximately $29,000,000 cost of upgrading and replacing the existing system cannot be supported by the current mill levy. As a result, moving forward with the radio system improvements may require multiple funding sources. These could be:

- **Voter approved bond for the majority of the initial capital cost**
  Given the life of the technology deployed, a bond duration of 10 to 15 years would be appropriate with the shorter duration being the best. The technology life of the system will be between 10 and 15 years so one does not want to still be paying for a system that needs to be replaced or updated.
- **Grant funding**
  Grant funding has generally been decreasing over the last several years. However, there are still some Homeland Security and Aid to Firefighter Grants available. These could be used to offset some of the capital costs and could possibly allow some work to progress prior to receiving funding though the voter-approved bonding process.
- **Bank financing**
  Bank loans could be used to fund a portion of the system, especially if the mill levy rate could be raised enough to provide debt service of the bank loans. The major drawback with this approach is the higher interest rates that would be paid on the loans.
- **User fees**
  Radio system user fees could be used to support the initial cost and the operation of the system. In many places, user fees provide the funds for the maintenance and operation of the radio system infrastructure. However, user fees are generally not popular with the users.
- **City and county general fund funding**
  The city and county governments could help fund their portions of the capital and operational costs of the radio system. This could be done within the normal bonding capacity of the local government entity or through direct appropriations. This approach is sometimes successful if a larger government entity can afford to pay for their portion of the radio system before other funding is available.

ADCOMM does not have a specific funding recommendation other than that Gallatin 9-1-1 will likely need more than one funding source and should try to obtain grants when possible.

Radio System Implementation Planning

The existing radio system has more or less grown "organically" over the last decade. There have been several system approaches that have been tried and for one reason or another were not successful. As a result, the existing system has a variety of different radio coverages and operating requirements depending on what frequency one is operating on. The goal of the new system is to provide an engineered system where the various system elements are designed to work together in a complementary fashion. Obtaining this result will require detailed system engineering as well as site development, project management, and system commissioning. This work will not be done in a few months. A project of this magnitude is likely a 48- to 60-month project including engineering and final acceptance. In addition, it is important to move the project forward in an approach that is cost efficient. To that end, ADCOMM recommends the following approach as outlined below. Note that these stages do not operate in a strictly serial fashion. There is considerable overlap. For example, once a site has been selected and engineered, the permitting process can start, even if other sites are still in the design or lease negotiation phase.

Stage 1 — Detailed System Engineering and Project Management

During this stage the following is completed:

- Detailed system design, drawings, specifications, etc. for:
  - The radio system
  - The microwave system
  - The radio sites and site improvements
  - The ancillary equipment such as DC power, alarm system, etc.
  - The installation of the equipment engineered above

In this stage, all of the final site selections would be made, and the process of working with existing and possible new site land owners would start to make sure the proposed site improvements would be acceptable to them.

This stage also includes project management, which occurs throughout the duration of the project.

Stage 2 — Radio Site Permitting and System Procurement

This step starts the radio site construction permitting process. There are several locations where sites will need to be developed and permitting is a pacing item—without the permits construction cannot start. While the permitting process is ongoing, decisions about how the systems will be procured will be made and the procurement process will occur. There may be a variety of procurement processes used depending on the equipment. For example, some equipment may be available on the WSCA or other purchasing contracts.[8]

Site permitting can be an especially onerous process due to not only local objections but also due to the Federal Communications Commission (FCC) tribal notification requirements. As a result, site development can take as long as 18 to 24 months.

At this point, ADCOMM is not recommending the system be procured as a single large system procurement. It is ADCOMM's experience that single large system procurements are very expensive as the system contractor would mark up the price of all the other systems from anywhere between 25 and 50 percent. It is our experience there is low risk to independently procure systems that have a well-defined interface to other systems. This includes things like the alarm system, DC power, microwave and data network, antennas, transmission line, and combiners, and site work.

System Implementation and Staging

As they become ready, the new equipment installation can occur. In some cases, the equipment and systems may be staged at either the factory or a local installation contractor's facility. This will depend on the specific system. For example, it might be possible to stage the microwave equipment as an entire system at the factory prior to shipping but it may not make sense to stage the radio system equipment at the factory, rather stage it at a local shop. This process would occur as sites are available since certain equipment is required to make other equipment functional; the installations would occur in this approximate order.

[8] http://www.naspovaluepoint.org/#/home/contracts

1. Site-related equipment including towers, shelters, etc.
2. Ancillary systems such as DC power, alarm monitoring equipment
3. Microwave and other system interconnection equipment
4. Radio system infrastructure
5. System commissioning (this would occur for each subsystem)
6. System acceptance (this would occur for each subsystem)

System Commissioning and Acceptance

After each system is implemented all of the technical parameters will be verified and final system adjustments made. At that time, drive testing and a sample set of users will be asked to use the system to get their input. In addition, user training will take place. After the system has been in successful operation for 30 to 60 days, it will be accepted.

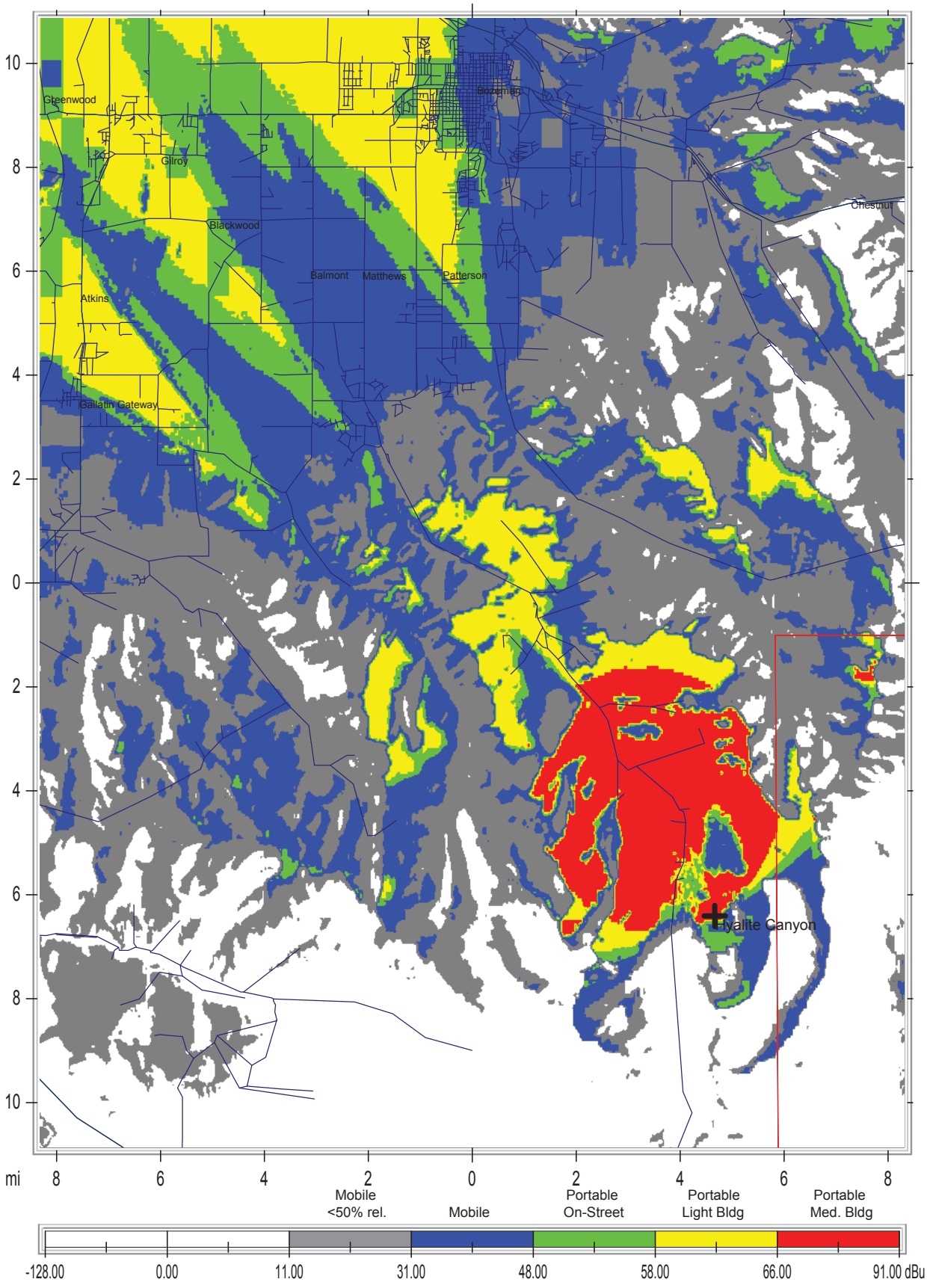
Final Project Closeout

Once the systems have been accepted, it will be critical to obtain all of the system documentation, as-built documents, training materials, and account for all of the equipment purchased. When this is done, the project will be considered complete. This process for closeout will occur during the project so that as-builts will be obtained and filed as the systems are completed.

Next Steps

If Gallatin 9-1-1 has some existing funding to start the detailed engineering process, we recommend this be done. This will help to move the project forward, provide some visibility that things are happening, and help refine the costs and site locations. This work can be moving forward while the remaining funding is being obtained.

Appendix A
Proposed Radio System Coverage Predictions (Composite)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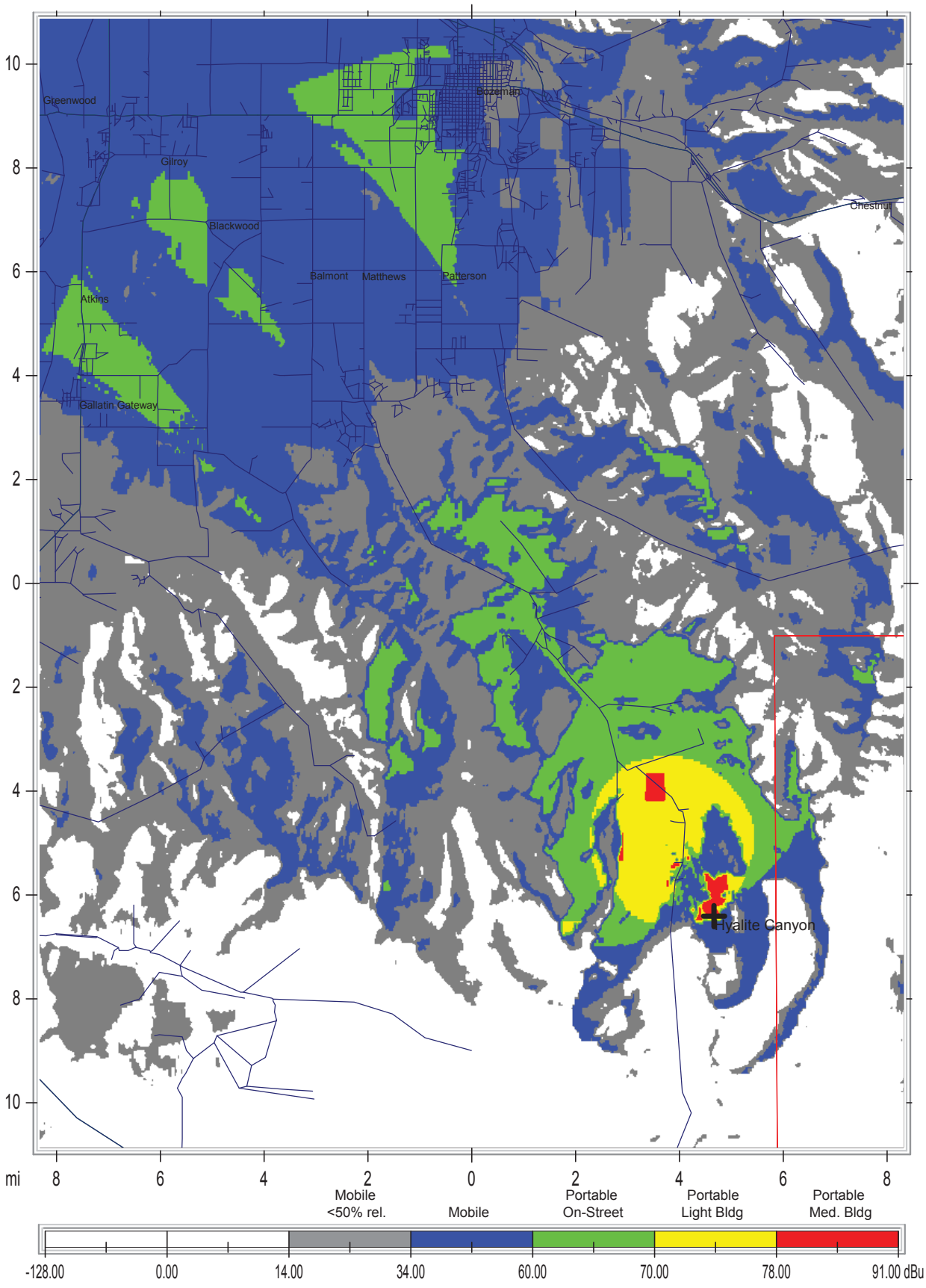
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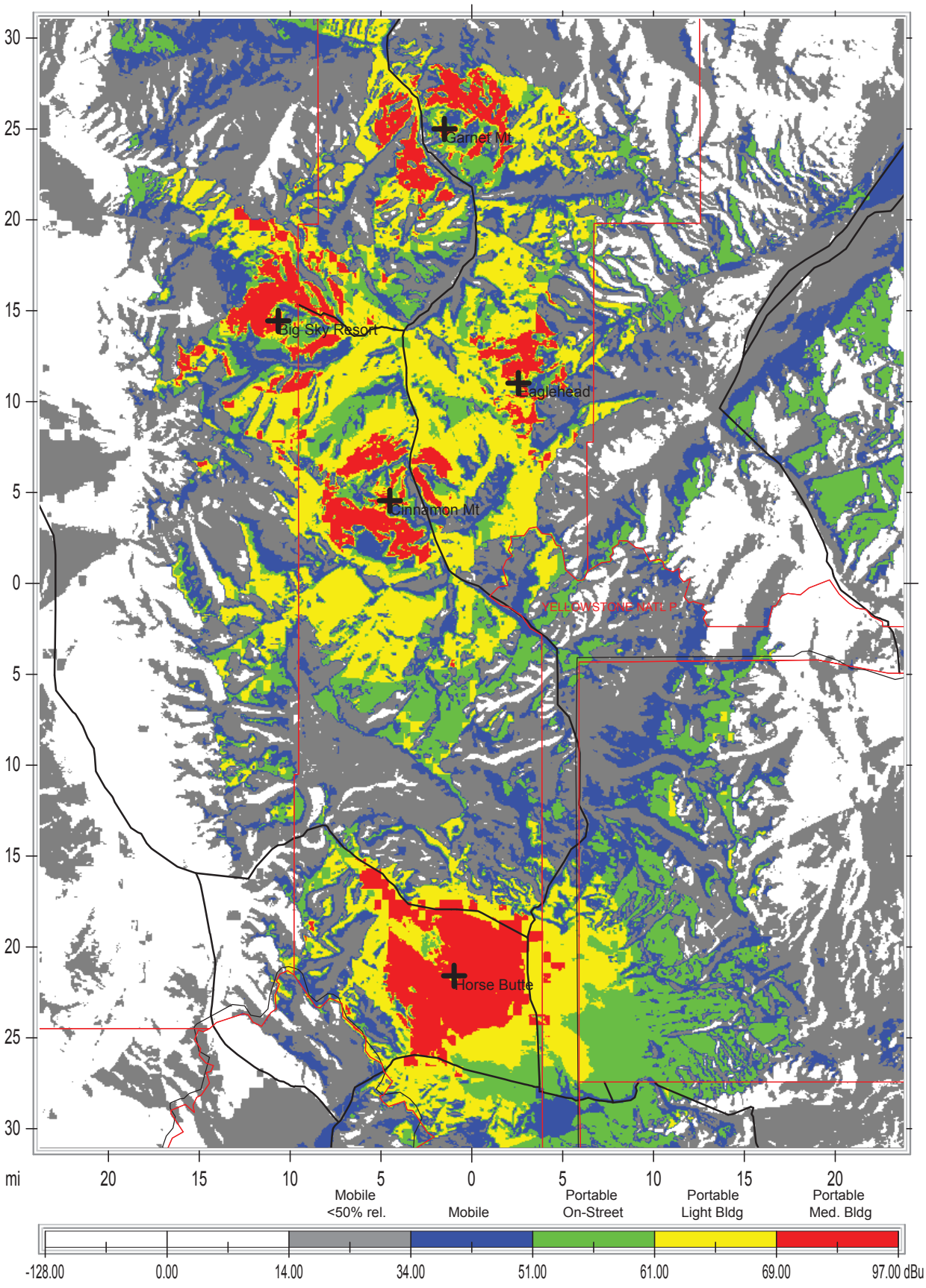
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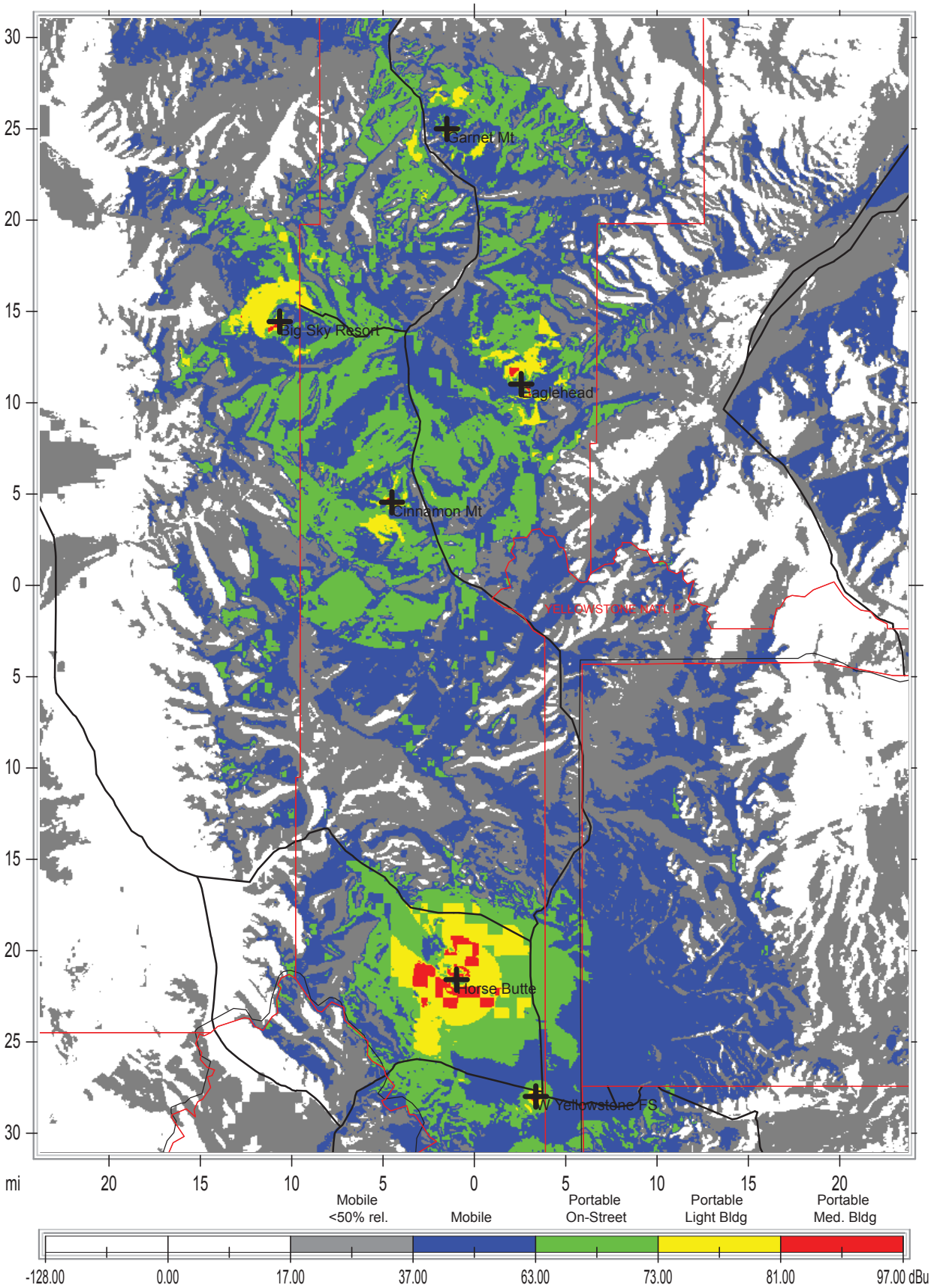
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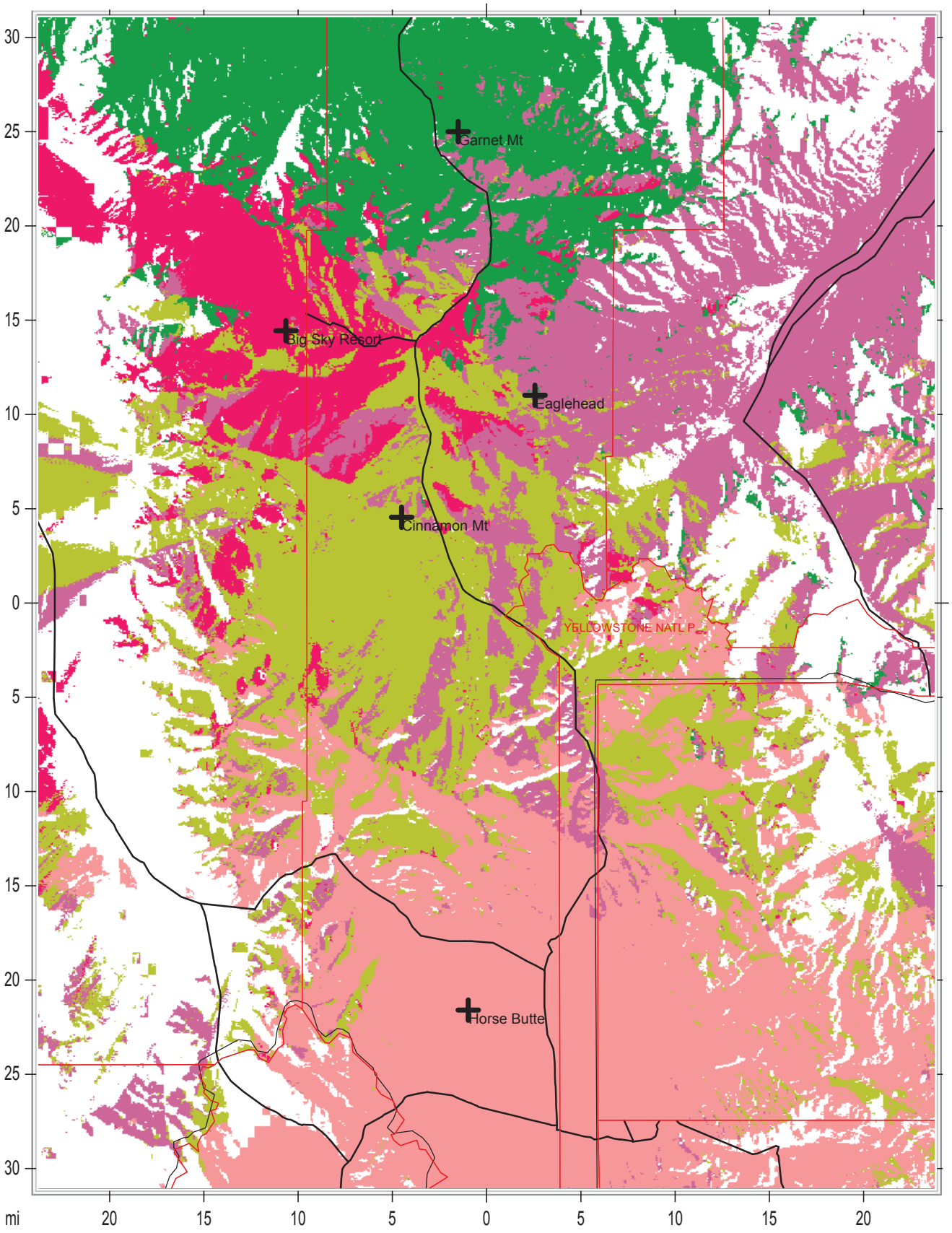
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