

Roscommon Equipment Center Program

Project Number 56

EVALUATING THE HUMMER® AND HMMWV SERIES CHASSIS FOR WILDLAND ENGINE USE



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Northeast Forest Fire Supervisors

In Cooperation with

Michigan's Forest Fire Experiment Station

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DISCLAIMER

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User's Caution...

A Note About Gross Vehicle Weight Ratings (GVWR)

American truck manufacturers have long relied on GVWR to designate the maximum allowable loading of their vehicles. The weight limits are carefully established through numerous design considerations including the strength and life expectancy of the frame, axles, springs, wheels, tires and powertrains, and most other components. Most manufacturers will not guarantee their products if users exceed GVWR specifications.

The U.S. Armed Forces are acutely conscious of the importance of vehicle reliability. They have insisted that manufacturers clearly specify vehicle gross vehicle weight.

At the present time, a large number of military vehicles are available to state and local agencies through federal government excess property programs and surplus sales. Many of these vehicles are being converted into fire fighting units. Those anticipating such conversions are urged to heed the GVWR limits, and other vital information posted on the dashboard of most of these vehicles. Federal excess property vehicles, on loan through State Forestry organizations, may be recalled if they are abused.

Blueprints and construction procedures prepared and issued by the Roscommon Equipment Center are intended to serve as guidelines for potential users of this equipment. It is possible that if all the options and alternatives specified on these drawings are used on any single vehicle, that GVWR limits may be exceeded.

Therefore, users are cautioned to:

1. Plan design and construction carefully,
2. Weigh each unit before actual duty assignment, and
3. Make whatever weight adjustments are necessary to bring the system into safe load limits.

Introduction

This study analyzes the U.S. Military M998 series and its similar commercial models, known as the HUMMER[®], for use as wildland fire engines. The project also includes information to design a unit for this use. It further compares the vehicle to other available cabs and chassis.

In the early 1980's, AM General Corporation designed what came to be known as the "High Mobility, Multi Purposed, Wheeled Vehicle" (HMMWV) for the US Military. The M998 Cargo Troop Carrier is the base unit of this group. These vehicles succeeded the M151 Jeep, M880's and Gama-Goat. At a 1988 meeting between wildfire agency and truck manufacturer representatives, AM General showed a desire to make the HUMMER available to fire fleets¹. The Roscommon Equipment Center (REC) program also had an interest to evaluate this vehicle anticipating future availability through Federal Excess Personal Property (FEPP). In 1989, the State of Michigan and AM General reached agreement which provided the Michigan Department of Natural Resources a HUMMER for evaluation. AM General Corporation had designed a prototype of a heavier duty vehicle for commercial purposes, referred to as the Heavy HUMMER. Michigan made the first purchase of such a unit. In 1992, AM General began offering the commercial version for public sale.

Design and prototype production of the fire package was done by the staff at the Michigan Forest Fire Experiment Station. The prototype went through three seasons of field evaluations, primarily in Michigan. Some evaluation was made in Nevada and Idaho, in conjunction with the USDI Bureau of Land Management (BLM). While built from the same base unit, the commercial HUMMER and the military HMMWV have some basic differences. This publication contains information about both these vehicles. The reader is cautioned to carefully discern between the two.

Publication of the drawings and additional technical information on the REC designs contained in this report is planned. Readers needing this information can check on the status of this project by contacting REC at the Roscommon address shown on the preceding page or through the REC web site.

HUMMER[®] is a registered trademark of AM General Corporation.

¹ The National Wildfire Coordinating Group (NWCG) Fire Equipment Working Team (FEWT) National Engine Subcommittee (NES) met with 15 manufacturers of trucks and specialty vehicles in Washington, D.C., in June, 1988. A major objective of that meeting was to encourage truck manufacturers to provide a more suitable chassis for wildfire control.

Vehicle Characteristics

In 1988, NWCG's National Engine Study identified important criteria for wildland fire vehicles. The HUMMER met most of the criteria established for off-highway forest fire control in its size class. This should not be surprising, since it was designed for a military mission profile of 40 percent off-road, 30 percent cross-country and 30 percent highway. Many characteristics make the HUMMER an ideal off-highway performer. Its ground clearance is a very high 16 inches, but its height is only 72 inches. Its length is about 180 inches with 72 degree approach angle (45 degree with winch), and a 45 degree departure angle. Bumpers added in the REC design decrease

these angles slightly. The underbody is well protected. The HUMMER's 85-inch width makes it about eight inches wider than the typical full size pickup truck box. However, this extra width and low 30 inch vertical center of gravity (at curb weight), gives it exceptional stability.

The chassis has a steel box construction frame. The body is made largely of glued and riveted aluminum sheet. The hood is a composite plastic. Components such as the drive line, exhaust system and fuel tank are located between the frame rails, forming a "hump" between the driver and occupant. Secondary

gear reduction is done at each wheel via a drop gear box, rather than all at the differential. This allows the vehicle to have a small differential and high (above wheel centerline) axle half shafts. The placement of these components results in the high ground clearance.

The engine is a General Motors (GM) V8 6.2 liter diesel², mated with a GM Hydra-matic 3-speed automatic transmission and a New Venture Gear 2-speed transfer case. The brakes are hydraulic inboard power dry disk

type, with brake lines well protected. Steering is power assisted with a 25-foot outside turning radius.

Commercial units come with radial tires. Until recently, most US military HMMWVs came with bias-ply tires. The cargo box of the 2-person cab model is shorter (83 inches) than a commercial pickup. The width between wheel wells is 52 inches. Figure 1 shows data on base units provided by AM General Corp.

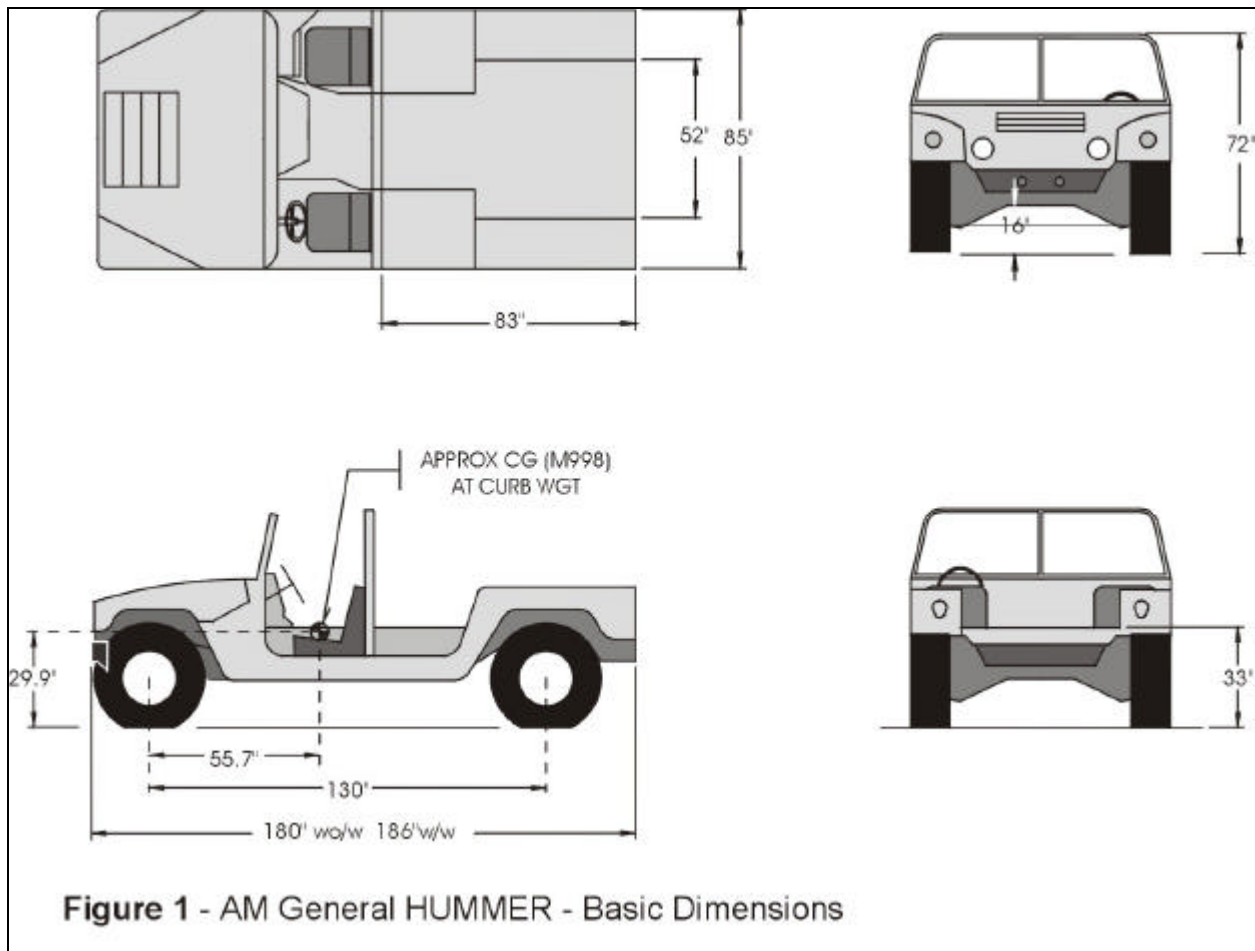


Figure 1 - AM General HUMMER - Basic Dimensions

²1998 Footnote. Newer HUMMER models utilize a GM 6.5 liter diesel. Commercial versions are available with a turbocharger option.

Differences Between Commercial & Military HUMMERS

The gross vehicle weight ratings (GVWR) of the original M998 military series ranges from 7700 pounds for the Cargo Troop Carrier to 9100 pounds for the Maxi-Ambulance model. The GVWR for the commercial version of the Heavy HUMMER is 10,300 pounds.³ For the military version (M1097) Heavy HMMWV Variant (HHV), it is 10,000 pounds.

The Heavy HMMWV/HUMMER has localized body reinforcements, improvements to the left frame rail and lower ball joints. It includes variable rate rear springs. Changes were also made to differentials and transfer case to increase their torque capacity and increase the axle and gear ratios. Front and rear prop shafts were changed to accommodate the other powertrain changes.

Commercial HUMMERS meet Federal Motor Vehicle Safety Standards (FMVSS) and have

other civilian modifications, such as 12 volt electrical systems, civilian style cab, sound insulation and comfort features.

The commercial Heavy HUMMER and military HHV became available in 1992. Military vehicles produced prior to that period, and many currently being produced, have the lower GVWR ratings mentioned above. If you obtain a HMMWV through sources such as Federal Excess Personal Property (FEPP), you should be aware of these internal differences. Make sure that you heed the GVWR and the gross axle weight ratings (GAWR) for that vehicle.

³1998 Footnote. Newer commercial versions are available with 12,000 lb. GVWR.

REC Prototype Design

To evaluate the commercial HUMMER prototype, REC staff designed and built the wildland fire vehicle shown in Figure 2. Goals were to:

1. Design a prototype wildland fire engine. Primary use; initial attack unit.
2. Test the HUMMER chassis in wildland field trials at full GVWR.

Appendix A summarizes the prototype's data, helping to show what was added by our design and what features came from AM General.

Table 1 shows the weights of various components utilized in the design and three coordinates that locate the approximate center of gravity for each component. The CGX coordinate is the horizontal distance in inches rearward from the center of the front wheel. The CGY coordinate is the horizontal distance

to the right of the vehicle's center line. The CGZ coordinate is the vertical distance above the ground. The nominal tank capacity was 300 gallons. With an operator, passenger, and full of fluids the vehicle's operational weight was near the specified GVWR of 10,300 pounds. Miscellaneous storage capacity was 240 pounds.

The tank and components were designed to keep the center of gravity low and provide clear vision to the rear for the operator. Designers found the need to be creative; the "small" sized bed of the HUMMER made space, not weight, the limiting factor in design. Utilizing the rear passenger area for pumps, hose reel and storage proved to be the most efficient use of space (see Figure 3). The calculated 36 inch vertical center of gravity was verified on AM General's tilt table. Approximately 40 percent of the load was on the front axle and 60 percent on the rear axle.

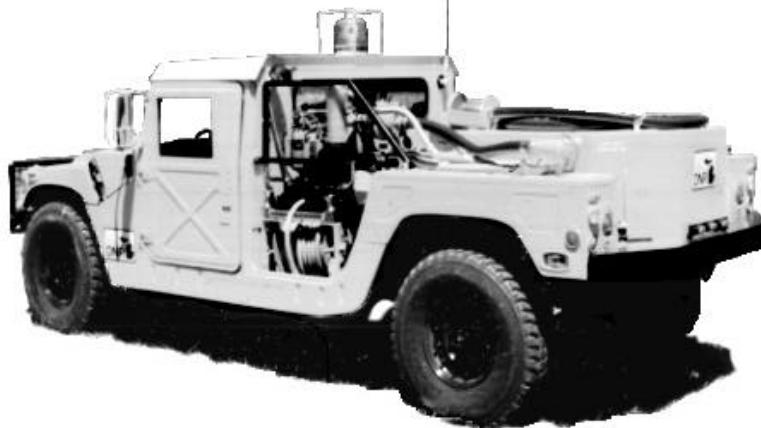


Figure 2 - The 300 Gallon Prototype "Heavy HUMMER" Designed for Project Testing

Table 1 – HUMMER Prototype Weights and Component Data

	Axle	Actual (lbs)	GVWR (lbs)
Axle Loading	Front	4,057	4,100
	Rear	6,242	6,501
	TOTAL	10,300	10,300

Water Capacity: 300 gallons

Component	Weight (lbs)	CGX (in)	CGY (in)	CGZ (in)
HMMWV (Base Vehicle)	5500	55.8	1.2	29.9
Water	2499	126.0	0.0	48.0
Tank	420	126.0	0.0	48.0
Tank Lid Assembly	73	126.0	1.0	57.0
Tank Mount Front	19	72.0	0.0	36.0
LH Reel w/Hose	135	86.5	-30.0	27.0
RH Reel w/Hose	135	86.5	30.0	27.0
Pump	170	91.0	-28.0	50.0
Pump Mount	41	92.0	-28.0	40.0
Pump Mount Adapter	10	74.0	-28.5	35.0
Fuel Tank w/3 Gallons	21	102.0	-28.0	45.0
Cab Roof	75	55.0	0.0	72.0
Cab Rear Panel	80	73.0	0.0	53.0
LH Door	45	56.0	-41.0	46.0
RH Door	45	56.0	41.0	46.0
Grill Guard	50	-20.8	0.0	36.0
Bumper, Front	45	-23.3	0.0	27.0
Bumper/Mount, Rear	97	163.0	0.0	36.0
Foam System	200	126.0	28.0	35.0
Operator	200	61.3	-30.0	40.0
Passenger	200	61.3	30.0	40.0
Storage	240	99.0	28.0	50.0
TOTALS	10,300	78.8	1.4	35.9

CGX = Distance (in.) rearward from center of front wheel.
 CGY = Distance (in.) to right of vehicle centerline.
 CGZ = Distance (in.) above ground line.



Figure 3 - The pump and left hose reel were mounted in the rear passenger area.

Tank Design

REC's 300 gallon tank design was the vehicle's most unique feature; the tank was suspended one half inch above the bed of the HUMMER on three isolator mounts (see Figures 4 and 5). These mounts were located on the vehicle's designed "hard points". Figure 6 shows the hard point locations. The tank had triangulated internal baffles that serve as a beam to support the bottom. This was necessary because the water load was not sitting directly on the bed of the vehicle. The tank overhangs the rear of the vehicle, with the sump extended below the bed into the bumper cutout. Figure 7 illustrates the locations and designs for the baffles, mounting brackets and sump. For strength and construction ease, the tank was made out of 14 gauge and 11 gauge steel sheet. Cold galvanizing protects the inside.

In off-highway situations, the HUMMER chassis was designed to flex. Avoid mounting rigid structures on the full bed length of this vehicle. If a rigid structure, such as a tank, is affixed to the vehicle, undue strain will be put on either the vehicle, the structure, or both, likely causing premature failures. Three years of field trials has shown that the suspended tank design gives the tank considerable freedom of movement. Both the vehicle and tank have shown no problems.

The HUMMER's 4-person cab style could utilize a similar tank of about 225 gallon capacity. In this case, the front section of the tank would be located between the rear passenger compartments. The profile of the tank would be approximately 4 inches lower. Pump and hose reel would need to be located on the tank top or fenders near the rear. Table 2 shows estimated weights for such a design. Storage weight allowance would be reduced from the 2-person prototype of Table 1. If more storage or area for accessories is needed, then water capacity would be less.

For vehicle testing, REC tried to maximize the water capacity of this unit; however, users requiring water volumes of less than 200 gallons should consider a tank that mounts between the "C" and "D" hard points. Eliminating the front section of our tank design would leave a capacity of approximately 200 gallons. The need to suspend the tank on isolators would be less critical for lower capacity tanks mounted between "C" and "D" points on the bed. Also, typical Fiberglass slip-on tanks of 200 gallons or less could fit this scheme. A 200 gallon model will be about 47 by 50 inches and about 24 inches tall. The tank's weight will center approximately over the rear axle. Figure 8 illustrates, and Table 3 estimates the weights for such a design. REC has not tested a HUMMER using a slip-on type tank.

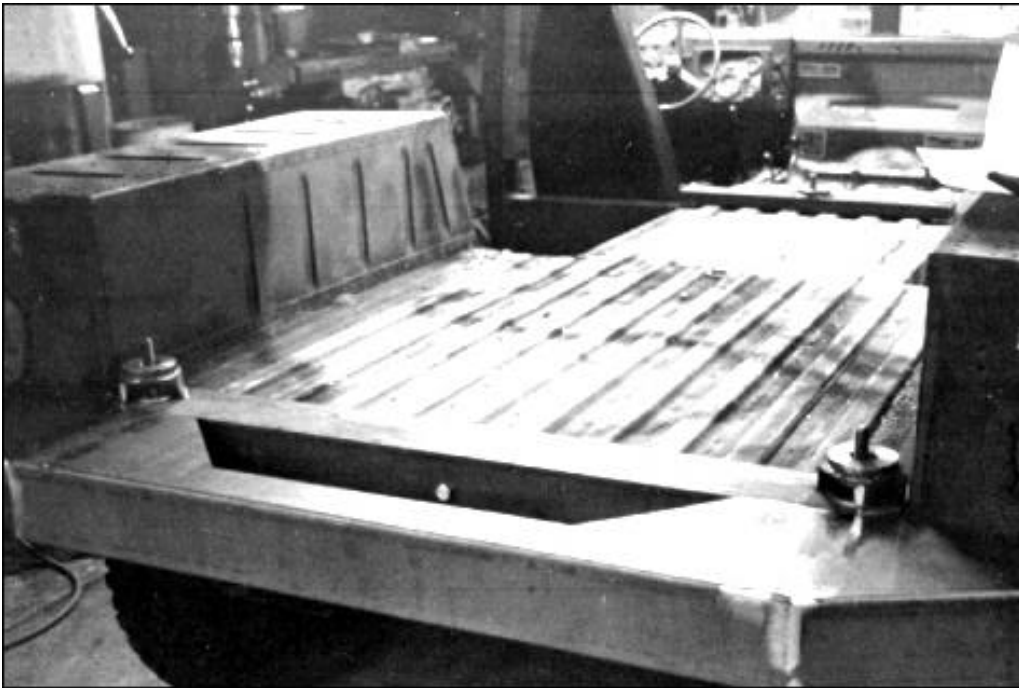


Figure 4 - The three tank isolator mounting points and the rear bumper with sump cutout.

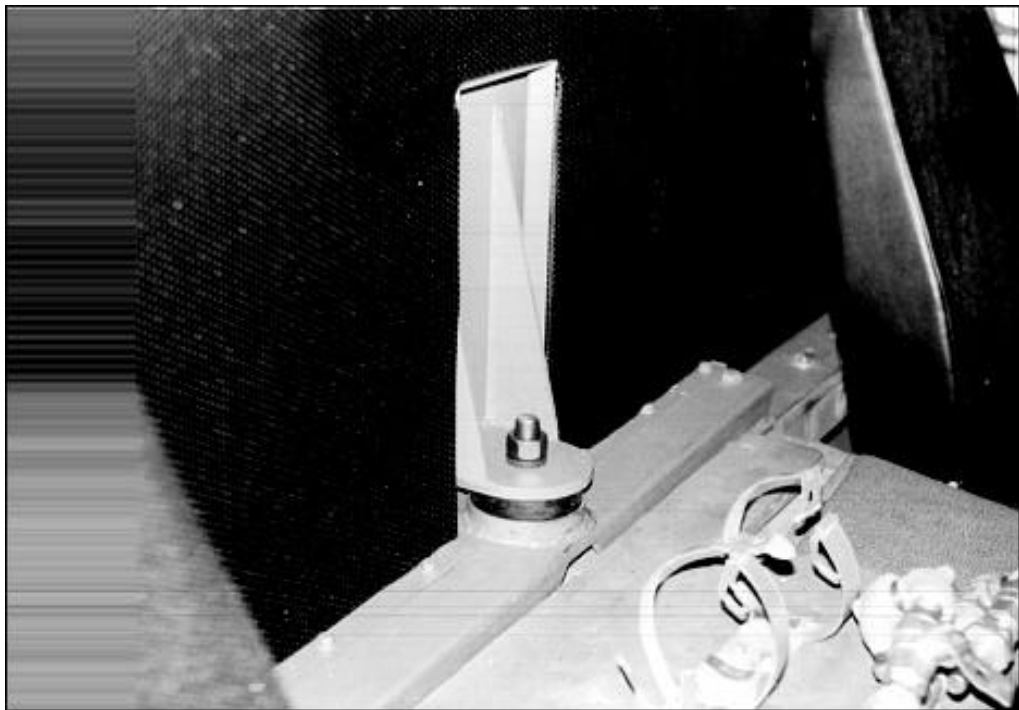


Figure 5 – Front tank isolator mounting point. Shown from inside the cab.

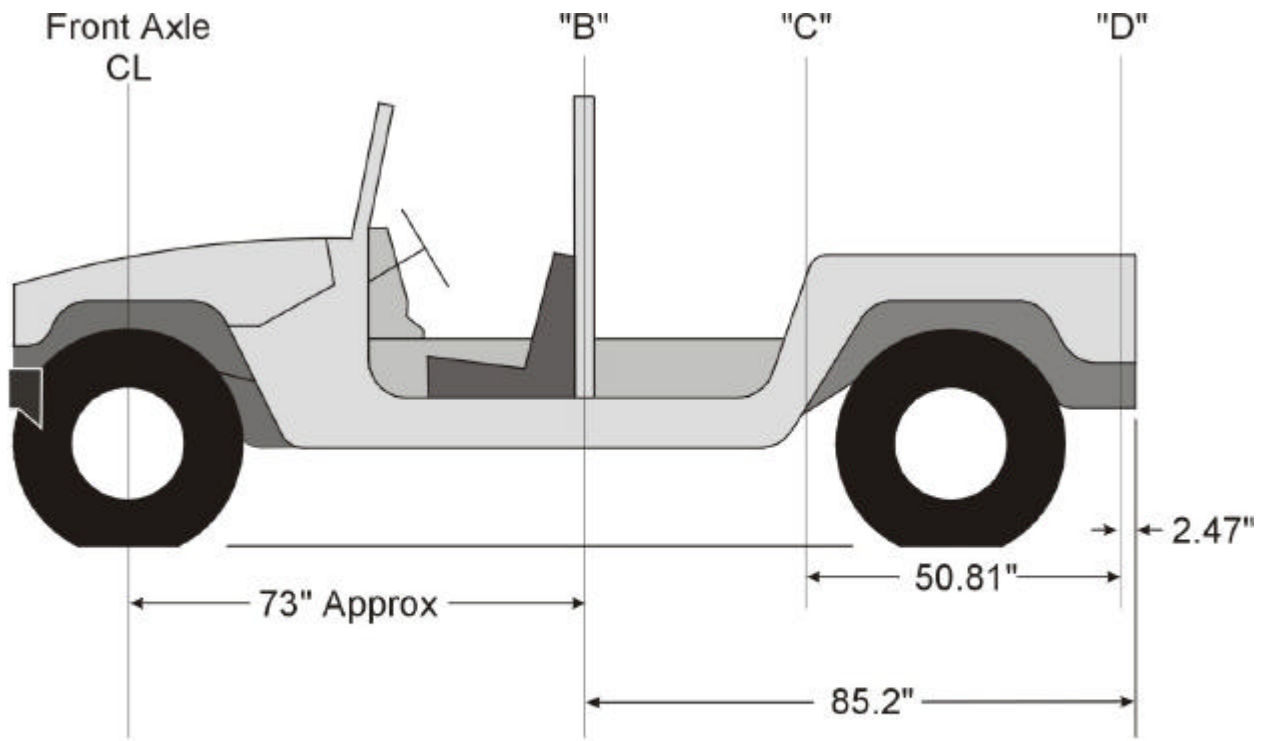


Figure 6 - HUMMER "Hard Point" Locations

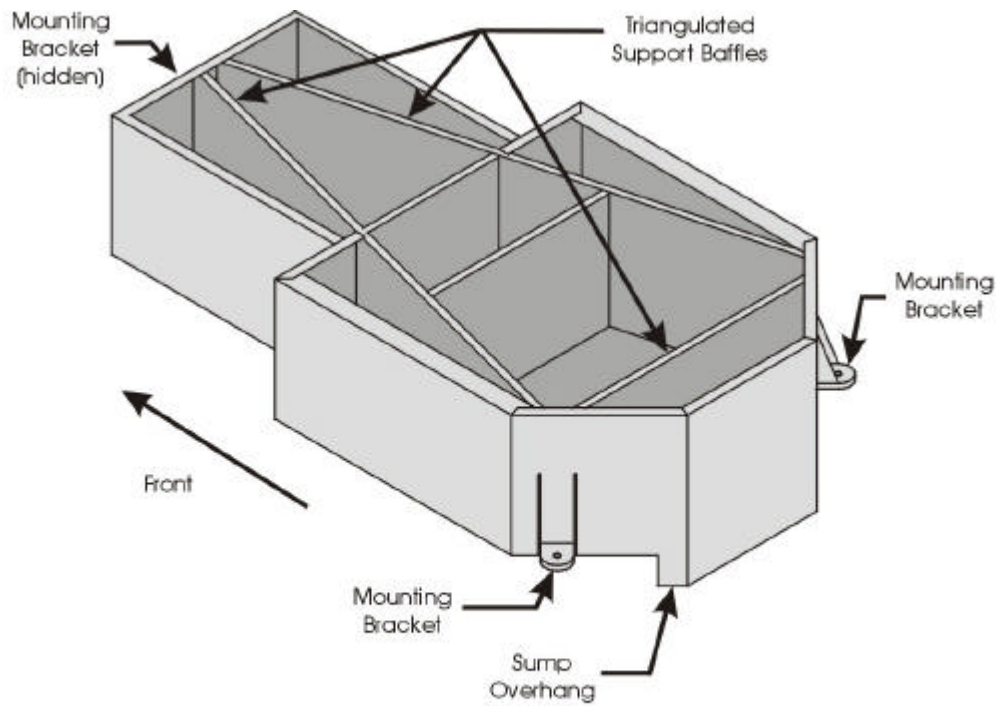


Figure 7 - Isometric View of 300 Gallon Tank without Cover

Table 2 – 4 Person HUMMER Estimated Weights and Component Data

	Axle	Calculated Weight (lbs)	GVWR (lbs)
Axle Loading	Front	4,084	4,100
	Rear	6,216	6,800
	TOTAL	10,300	10,300

Water Capacity: 225 gallons

Components	Weight (lbs)	CGX (in)	CGY (in)	CGZ (in)
HUMMER 4-Door (Base Vehicle)	6,587	60.0	1.2	31.0
Water	1,874	130.0	0.0	44.0
Tank	370	130.0	0.0	44.0
Tank Lid Assembly	73	130.0	10	53.0
Tank Mount Front	19	72.0	0.0	36.0
Reel w/Hose	135	130.0	-30.0	65.0
Pump	170	130.0	-28.0	60.0
Pump Mount Adapter	10	130.0	-28.5	54.0
Fuel Tank w/3 Gallons	21	130.0	-28.0	60.0
Grill Guard	50	-20.8	0.0	36.0
Bumper, Front	45	-23.3	0.0	27.0
Bumper/Mount, Rear	97	163.0	0.0	36.0
Passenger, Rear	200	92.0	-30.0	30.0
Passenger, Rear	200	92.0	30.0	30.0
Operator	200	61.3	-30.0	40.0
Passenger	200	61.3	30.0	40.0
Storage	49	130.0	28.0	50.0
TOTALS	10,300	78.5	0.4	34.8

CGX = Distance (in.) rearward from center of front wheel.
 CGY = Distance (in.) to right of vehicle centerline.
 CGZ = Distance (in.) above ground line.

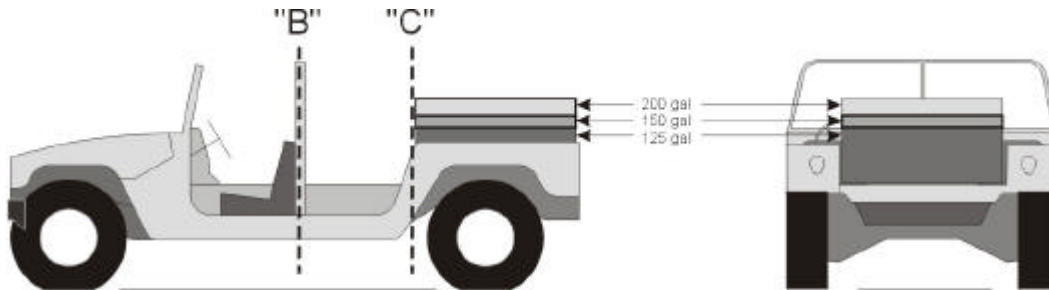


Figure 8 - Slip-On Tank

Cab Design

REC designed its own cab before AM General designed its 2-person commercial cab. This design can be used to upgrade a canvas cab if re-utilizing a military vehicle. Doors of the type found on HMMWV basic armor units were used. Civilian HUMMER doors are suggested if available. The cab top and rear panels were made of 14 gauge steel. Rubber isolator

mounts were used to attach the cab top to the windshield so that the top would not restrict the flex of the vehicle (see Figure 9). The “B” hard point to which the front of the tank is mounted is located inside the cab. Cutouts in the rear panel were necessary to incorporate the front tank mount. This area must be sealed properly, otherwise water lost through tank vents, or other sources, will enter the cab area when traveling downhill.

Table 3 – Estimated Weights for 200 Gallon Fiberglass Slip-On Tank

	Axle	Calculated Weight (lbs)	GVWR (lbs)
Axle Loading	Front	4,047	4,100
	Rear	6,226	6,501
	TOTAL	10,273	10,300

Water Capacity: 200 gallons

Components	Weight (lbs)	CGX (in)	CGY (in)	CGZ (in)
HMMWV (Base Vehicle)	5,800	52.9	1.2	29.9
Tank & Water	1,955	132.5	0.0	48.0
RH Reel w/Hose	135	125.0	0.0	27.0
Pump	170	145.0	0.0	50.0
Fuel Tank w/3 Gallons	21	102.0	-28.0	45.0
Grill Guard	50	-20.8	0.0	36.0
Bumper, Front	45	-23.3	0.0	27.0
Bumper/Mount, Rear	97	163.0	0.0	36.0
Foam/Miscellaneous	200	126.0	28.0	35.0
Operator	200	61.3	-30.0	40.0
Passenger	200	61.3	30.0	40.0
Storage	1,400	99.0	0.0	50.0
TOTALS	10,273	78.8	1.2	36.9

CGX = Distance (in.) rearward from center of front wheel.
 CGY = Distance (in.) to right of vehicle centerline.
 CGZ = Distance (in.) above ground line.

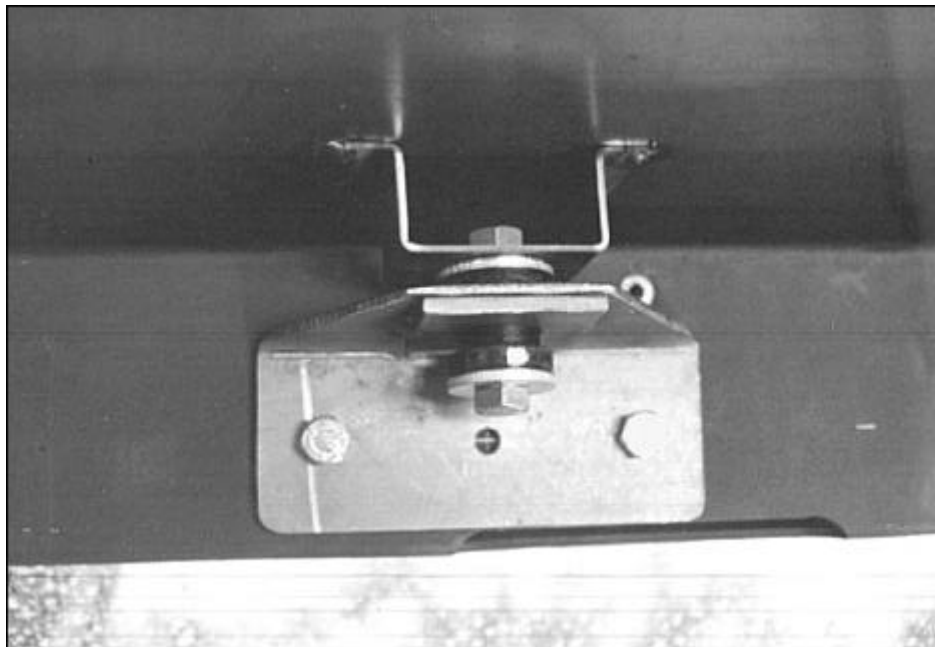


Figure 9 – An isolated cab mount for the REC design. They are inside, on the windshield frame.

Front Bumper And Grill Guard

HUMMER units with a winch have a strong bumper that covers about the middle one third of the vehicle's front. To help protect the front corners of the vehicle, REC designed bumper extensions that cover the width of the vehicle (see Figure 10). Because the front wheels are positioned far forward on the vehicle, the bumper must provide adequate clearance for tire movement. REC's design is lightweight, but proved adequate during field trials.

The US Military has reported some problems with damage to the front right corner of hoods. This was usually caused by drivers who were unfamiliar with the HUMMER's extra width. The grill guard designed for this project helps the driver to better locate the right corner of the vehicle and provides protection to the front of the vehicle from brush and limbs. It will fold forward, to allow the hood to open for service (see Figure 10).



Figure 10 – Bumper extensions and a folding grill guard.

Rear Bumper

The rear bumper was designed to protect the tank sump which overhangs the rear of the bed. It was also utilized to mount a 5-gallon aluminum foam concentrate tank.

Auxiliary 12-Volt Electric System

Commercial HUMMERS come with a 12-volt electric system. Our prototype, however, had a

24-volt system. We obtained a 5 belt water pump fan pulley that is used to drive an air conditioner on some HMMWV ambulance models. This provided an extra groove to drive a 12-volt alternator. The alternator was mounted in the space available for the air conditioner (see Figure 11).

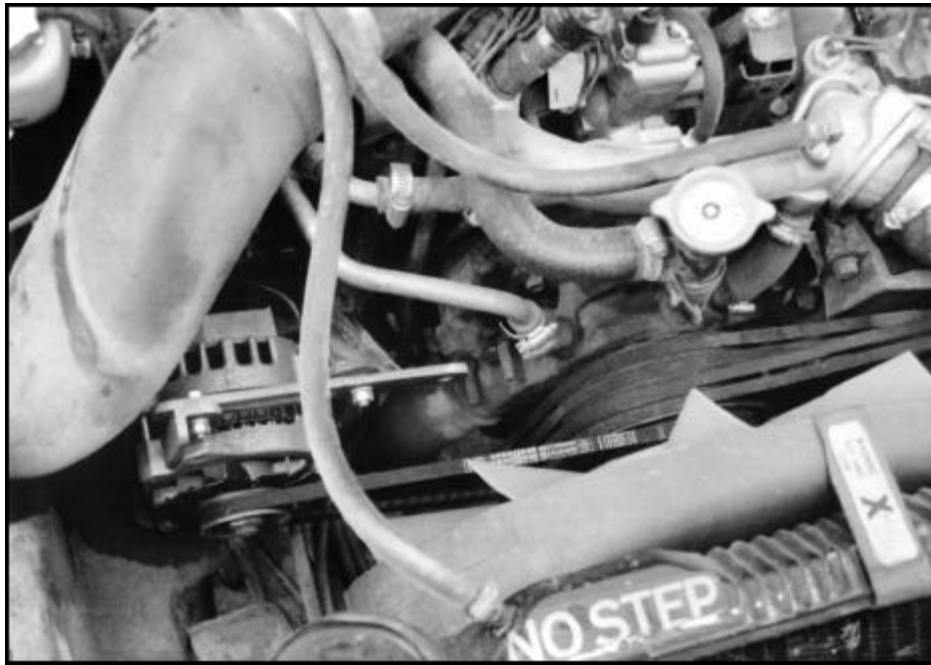


Figure 11 – 12 Volt Alternator Mounting

Converting Military HMMWV'S to Fire Units

At this writing, Military HMMWVs have not been available from FEPP. We would not expect vehicles through this program until about 1998. As mentioned earlier, the M998 series HMMWV have load capacities less than the REC prototype unit. Tank capacity will need to be smaller. Table 4 shows the military designations, weight ratings and expected maximum water capacities for the Military HMMWV models. The US Military assigns weight ratings based on the needs of each model's mission. Because of this, different models, with essentially the same chassis, may have different weight ratings. *Despite this, those re-utilizing former military vehicles are obligated to heed each individual vehicle's weight ratings.*

REC prepared Table 4 by combining information obtained from AM General with estimates calculated from design experience with its 300 gallon unit. Some of the most common models, such as the cargo troop carrier, have load capacities substantially less than the Heavy HMMWV (M1097) variant. While their capacity is low, they may be ideal patrol or command

vehicles. They could be very useful for moving supplies and tools into remote areas. As mentioned earlier, tanks with volumes of less than 200 gallons would be best positioned between the "C" and "D" hard points. Their center of gravity would be directly above or slightly behind the rear axle. *For most military models, the amount of weight that can be added to the front axle, without exceeding the front GAWR, will be minimal.*

The REC cab design replaces the canvas cab found on many of the military vehicles. For many models, the addition of the 200 pound cab will limit additional load on the front axle. In Table 4 we predict which military models can add the REC bumper and grill, without exceeding the front GAWR.

Before adding equipment to any of these vehicles, the user should strip the vehicle of unnecessary military hardware and take it to scales to determine the vehicle's total weight and weight on each axle. Subtract these weights from the appropriate weight ratings of the vehicle. This will show the maximum weight

that can be added without overloading. When estimating the weight, be sure to include the weight of the operator and passengers. *Before putting the unit in service, have it weighed again full of water and all its equipment. It should not exceed the weight ratings.* Also, make sure the

vehicle has standard lighting (turn signals, clearance and identification lights). For more information on completing the unit for wildfire control use, see REC's Guidelines for Designing Forest Fire Engines. An on line version is available at the REC web site.

Table 4 – Ratings and Expected Water Capacity Limits

Model Designate	Winch Model ¹	Description	Ratings (lbs.)			Curb Wgt (lbs.)	Est. Water Capacity ² (gal.)	REC Grill
			GVWR	FAWR	RAWR			
M998	M1038	Cargo Troop Carrier	7,700	3,350	4,350	5,200	100	No
M1025	M1026	Armament Carrier, Basic	8,200	3,685	4,515	5,960	135	Yes
M1043	M1044	Armament Carrier, Sup. Armor	8,400	3,961	4,439	6,411	160	Yes
M966	M1036	TOW Missile Carrier, Basic	8,200	3,550	4,650	6,051	150	No
M1045	M1046	TOW Missile Carrier, Sup. Armor	8,400	3,725	4,675	6,438	160	Yes
M997 ³	---	Maxi-Ambulance	9,100	3,860	5,240	7,180	200	No
M1035	---	Ambulance, Soft Top	7,700	3,350	4,350	5,297	100	No
M1037	M1042	Shelter Carrier	8,660	3,362	5,298	5,424	200	No
M1097	---	Heavy HMMWV Variant	10,000	3,565	6,435	5,600	300	Yes

¹Winch adds 127 pounds to curb weight and increases vehicle length by 6 inches.

²Assumes vehicles are stripped down to base vehicle (5,200 pounds curb weight).

³The M997 has a reduced military mission profile, the GVWR has been adjusted upward for that mission. We recommend that it be treated as an M1037/M1042 Shelter Carrier, and have estimated the water capacity accordingly.

Field Use Evaluation

The design criteria used to develop the HUMMER series called for a vehicle that could handle extreme grades, off-highway obstacles, as well as highway driving. Three years of field experience responding to forest fires has shown this vehicle to be exceptional as a light weight, maneuverable, off-highway unit. During this time we saw no sign of damage or deterioration of the chassis and components, carrying this relatively large load off-road.

Highway performance was more than adequate and better than might be expected from a military vehicle. It can top 65 MPH with a full load. Acceleration was very adequate, although some power loss was encountered when the cooling fan kicks in. According to AM General, this power loss is substantially reduced for the commercial model. Road noise was louder and operator comfort somewhat less than what would be expected from more typical commercial vehicles. The seats of the commercial HUMMER, however, were quite comfortable. Field trails showed that operators

taller than 6'4" will feel cramped when driving a 2 passenger model. Those taller than 6' would utilize more room if it were available. The commercial 4-person cab model provides better leg room for the driver.⁴

Off-the-road, performance was exceptional. Having the wheels at the corners provides a relatively long wheel base and a wide track helps with stability. The commercial version, with the variable rate rear springs and radial tires provide an exceptional ride, even at full GVWR. The Central Tire Inflation System (CTIS) allowed regulation of the air pressure to suit any type of terrain. During our tests we drove over washboard roads, loaded at GVWR, at 50 miles per hour with virtually no steering problems or discomfort to the operator. This means that expensive components, such as pumps, valves, radio equipment and the tank

⁴ 1998 Footnote. AM General has made leg room improvements in the more recent commercial models.

itself experienced less vibration and jolting, possibly saving on their wear and tear.

Studies conducted by the US Military showed that M998 HMMWVs could traverse a significantly higher percentage of terrain than its predecessors, the M151A2 Jeep, M880 5/4 Ton Truck and Commercial Utility Cargo Vehicle (CUCV).^{5 6 7}

The HUMMER generally looked and drove like an automatic transmission, light duty truck. There were some basic differences. The powertrain was designed to utilize the engine retardation in conjunction with the transmission for braking. Hence, operators should use the automatic as though it were a manual transmission, utilizing the brake to provide final resistance to come to a complete stop. The brakes were also used to modulate the action of the differential. If an operator gets in a position where a wheel begins to slip, slight pressure to the brake provides enough resistance to lock the differential, giving tractive effort back to the opposite wheel. The HUMMER was not a difficult vehicle to drive, but operator training is recommended to take full advantage of this vehicle's abilities. The AM General Corporation has a staff which trains trainers in driving this vehicle.

The body of the vehicle suffered some minor abrasions and dents from its use. All in all, the aluminum held up well and was more durable than typical sheet metal truck bodies. We found no performance problems with the engine. We did have a problem with a leak in the transmission cooler. Also, one axle half shaft broke during the vehicle's tour of duty in Idaho. In this case, a wheel lifted off the ground at high speed. When it returned to the ground, the torque spike broke the half shaft. This was a single and severe incident. We found no evidence of frequent axle failure for these vehicles.

⁵ Smith, Robert P., *Mobility Comparison of the High-Mobility Multipurpose Wheel Vehicles (HMMWV) and the Commercial Utility Cargo Vehicles (CUCV)*, U.S. Army Engineer Waterways Experiment Station. Technical Report GL-83-8, 1983.

⁶ The M880 was essentially a commercial pickup truck much like today's 1-Ton commercial versions. The CUCV was a commercial vehicle based on the Chevrolet Blazer.

⁷ The military units did not have radial tires or CTIS for these tests.

We did have some problems with the Central Tire Inflation System. In general the system performed well. Twice, while in western climates, with high ambient temperatures, a plastic air line routed near the exhaust, melted. This caused the loss of air in both front tires. This information was given to AM General and changes were made to prevent this occurrence. A third incident occurred with the CTIS that is perhaps more difficult to solve. While working on a fire, the rear air line of the vehicle was pinched and a guard for the system damaged. After the incident, the unit lost air pressure in both rear tires while driving down the highway. We feel that the CTIS lines, as designed by AM General, were protected as well as practical, but this last incident showed some vulnerability when working in areas with stumps, slash, or other obstacles. The CTIS can be disabled so that the tires can be filled individually, in the traditional way. A fitting was added near the air compressor so we could use a small coiled airline to fill any of the tires in case of any future CTIS failures. We highly recommend adding this auxiliary air fill hose to any CTIS unit.

Our original tank design used a rubber insert type fastener, called a "well nut" to hold the lid down. This was an attempt to provide a quicker and easier lid hold-down system. However, the weight of the water in the steep grades of the western states caused these fasteners to fail. Changes in the design have been made to rectify these problems. Also, additional cab sealing and changes in the tank vent were incorporated because of water leakage into the cab. Again, this was the cab designed and fabricated by REC.

In general, the vehicle received a very positive response when utilized for initial attack purposes. It was also used to help transport supplies on the "Foothills" fire in Idaho in 1992. Fully loaded, the vehicle traversed dozer line built in steep grades, delivering supplies to areas where other available wheeled vehicles could not go. There was a desirability, by those utilizing it in the western states, for more storage. This could be accommodated, of course, by reducing the water load and building in storage cabinets.

At the time of testing, AM General's dealer network had not been established. During field trials, repairs were made by Michigan DNR personnel with parts support directly from AM General in South Bend, Indiana and Livonia,

Michigan. While operating in Nevada and Idaho, BLM and MDNR personnel found assistance from the National Guard. At this time the quality of dealer service is unclear, but

a dealer network has been established. Those who utilize military vehicles probably have shops or sources for repair. Others will need to rely on the dealers.

Costs⁸ and Specifications

The base cost of the 2-door commercial HUMMER chassis is about \$40,000. The final cost will depend on options. Major options that wildland fire users may wish to consider are a 12,000 pound winch, central tire inflation system (CTIS), run flat tire system, driveline protection and brush and stone guards. The vehicle comes in 2-person and 4-person cabs.

The only lifetime cost study between the HUMMER and other commercial chassis was done for a fire department type initial attack vehicle.⁹ The study concluded what we believe will be a similar case in wildland fire. Compared to commercial 1-Ton pickup units, the initial cost of a HUMMER was about twice as much; however, the expected lifetime was two to three times that of the pickup chassis unit. This results in a long term cost savings by reducing the number of chassis needing replacement, plus the cost of outfitting the vehicle with pump and tank. Military style vehicles are produced with few changes over a longer period of time than commercial chassis. For users such as fire control, who have low annual usage but long lifetime vehicles, this continuity means better parts availability when the vehicle gets older. It also means a reduction in fire apparatus design changes caused by chassis design obsolescence. The highway abilities of commercial 1-Ton chassis and HUMMER are about the same, but the HUMMER will have substantially better off-road capability and twice the off-road payload capacity. These reasons more than justify the HUMMER's high up front costs for off-highway use.

The commercial HUMMER has options that may be of interest to forest fire control. These should be considered before ordering the

vehicle. A quick run-down on these options follow.

Central Tire Inflation System (CTIS)

A vehicle's tires act as springs, affecting the ride. Adjusting the air pressure in the tires changes the spring rate. CTIS should be considered for those vehicles that will spend a lot of time off-highway, since it can help protect valuable equipment on the vehicle by reducing load shock. Additionally, greater traction can be gained by having a bigger footprint. CTIS does add some additional maintenance and complexity to the system. Consider this option if your vehicle faces situations of very poor traction or rough terrain. The expected cost for CTIS will be about \$2400.

Winch

A 12,000 pound electrical winch is offered by AM General. During field trials, the winch was not needed to recover the vehicle. The HUMMER, of course, can get stuck and we did experience this during training. When this vehicle does get stuck it may not be in a convenient place for another type of vehicle to reach. The winch option would add approximately \$2000 to the price.

Run Flat Tire System

A run flat tire system is available for the HUMMER. Run flats are a rubber, inner ring, mounted on the wheel rims inside the tires. These were developed for the military to allow a vehicle with a flat to "limp" at up to 30 MPH back to safety. The cost varies, depending on whether CTIS is installed. We did not test this system.

Brush and Stone Guard

These guards for the front grill area of the vehicle are available for about \$250. These do

⁸ Cost estimates from 1993.

⁹ Ciarula, Thomas A., *A Cost Analysis and Feasibility Study of Using an US Army XM1097 (Heavy HUMMER) Chassis to Build an Initial Attack Fire Apparatus: MSA-685*, Central Michigan University, 1991.

not give as much protection as those designed by REC, but may be adequate for some users.

Driveline Protection

Our unit came with this option, but was removed prior to testing. The driveline protection is a relatively light weight, tubular, grid work that will protect some of the underbody components from obstacles such as logs or rocks. We felt, that in the heavy eastern fuels, it could catch and drive debris up and into components, causing more problems than it solved. The cost is about \$1000 but, in our opinion, underbody components of the vehicle are well placed and elevated to avoid damage from off-road obstacles. We do not think these are necessary. Those who operate primarily in rocky areas may wish to make their own evaluation.

Rocker Panel Protection

Additional protection to the rocker panel is available. We did not evaluate this option.

Special Equipment Applications Guide

This publication lists important vehicle data. It includes weights, dimensions, electrical diagrams and other information useful to those modifying the vehicle for special purposes. This book will save the modifier time and provide information necessary for a proper design. It is highly recommended. The cost will be small.

Cab Style

The vehicle is offered in 2 and 4 person cabs. The 4-door will cost about \$2000 more than the 2-door. The 4-door cab will reduce the payload by the weight of the additional occupants, but more importantly, will reduce the amount of space available for adding equipment.

Summary

REC is well familiar with the current line up of commercial 4x4 commercial (pickup) trucks. The AM General HUMMER was evaluated in part to compare its performance to that of the commercial pickup chassis; there is little comparison. With the constant full load situation of a fire vehicle, we believe the life expectancy of the HUMMER will be at least twice that of a commercial 1-Ton 4x4. The water capacity will also be approximately twice as much. The mobility and off-road performance, primarily because of the HUMMER's underbody clearance, will be much more than other vehicles of its size. But, these come at a price: the user will pay twice the cost for the base chassis.

The user should be aware of the differences between the commercial HUMMER and military HMMWV chassis. Besides having a 12-volt electrical system and a sedan style cab, the commercial unit has differences in power train, springs, and body construction to increase its payload. Those converting military vehicles to fire units should heed the GVWR labels for that vehicle. Fire apparatus designed to fully utilize

a commercial HUMMER unit will overload most military units.

Our test HUMMER was utilized primarily as an initial attack water unit. It also had utility as an off-road mop-up unit, by combining the 300 gallon water capacity with a Class A foam system. It was excellent for use as a patrol vehicle and for carrying supplies in off-road situations.

The low profile design made this vehicle extremely stable and allowed it to drive underneath many tree canopies and obstructions. Military studies found that the HUMMER could traverse significantly more terrain than its predecessor Jeep, M-880 or Commercial Utility Cargo Vehicle. The radial tires and CTIS on our test unit enhanced the mobility over standard bias ply military HMMWVs.

Despite its design for off-highway performance, this vehicle performed more than adequately on the highway. It is probably the best lightweight off-highway wheeled vehicle available today. In many ways, it reminds us of the Dodge Power

Wagon of old. The 1960 vintage Power Wagons are still used by many as the yardstick of what a forest fire control vehicle should be. The capacity of the commercial HUMMER rivals that of the old Power Wagon. Its maneuverability and off-highway performance is better than that of the Power Wagon. We expect its durability to compare very favorably.

The differences come mostly in style and space available for placing equipment.

While for many agencies, initial chassis cost will be a definite negative factor, the HUMMER comes highly recommended, based on our experience, for the tasks listed above.

Appendix A
Specifications for AM General's Heavy HUMMER®
With Michigan DNR Wildland Engine Package*

Base Vehicle (as delivered):

Type: Cargo/Troop Carrier with Winch and Soft Top 2-Person Cab

Modifications from standard military vehicle:

- Winch capacity: 12,000 Lbs.
- Upgraded Gross Weight Rating to 10,300 Lbs.
- Central Tire Inflation System (CTIES)
- Radial Ply Tires
- Keyed Ignition
- Hard Doors (basic armor type)
- Non-Military Light Switch (headlight)
- FMVSS Lighting

Michigan DNR Modifications:

Operator and Vehicle Protection:

- Steel 2-person cab
- Front bumper extensions (extend existing bumper to width of vehicle)
- Rear bumper added \Grill guard

Water Tank:

- Capacity: 300 gal.
- Material: Mild steel with aluminum cover, galvanized interior
- Mounting: Tank suspended on a 3-point shock isolated system to minimize affect of the vehicle's frame flexure

Water Handling (with capability to draft):

Pump: Wajax Model BB-4
Type: Gasoline engine driven 4-stage centrifugal

Performance:	PSI	50	100	150	200	250	300
	GPM	110	105	90	80	70	56

Hose Reel: Hannay 6024-19-21

Two hose reels mounted to allow access from each side of the vehicle 24-volt electric rewind.

Foam System (for Class "A" foam)

Proportioner: KK "PROportioner"

Nozzle: Air aspirated type

Concentrate Reservoir: 6 gal. 6061 aluminum tank mounted at rear of vehicle

Electric:

12-volt auxiliary system to operate radios, siren, rotating beacon, pump engine starting, auxiliary lighting, and foam proportioner. Charging system, belt driven 85 amp. Alternator.

* The Michigan DNR purchased an early prototype of the commercial "Heavy HUMMER". This base vehicle was a modified M998 military vehicle with upgraded load capacity. Some, but not all, of the commercial HUMMER features were incorporated into this unit.