September 2005 Article of the Month
By *Rod Machado*

In-flight Emergencies - Part 1

How to Crash-land an Airplane

My wife was considering the purchase of a handkerchief for my last birthday present. Unfortunately she didn't know my nose size. She kids me about this because my nose size keeps changing. I keep running into solid objects with it. Several months ago I walked into a door at 2 mph, bounced back and fell on my derriere. That hurts! Now, my nose is so big that, when I lie down in a sailboat, it changes direction.

Running into a door at 2 mph is a very uncomfortable experience. It is not, however, a deadly one. But imagine hitting something solid in your airplane at 100 mph. If a 2 mph collision can swell a nose, a 100 mph collision can eliminate one. Pilots sometimes face similar consequences when an engine failure occurs over inhospitable terrain.

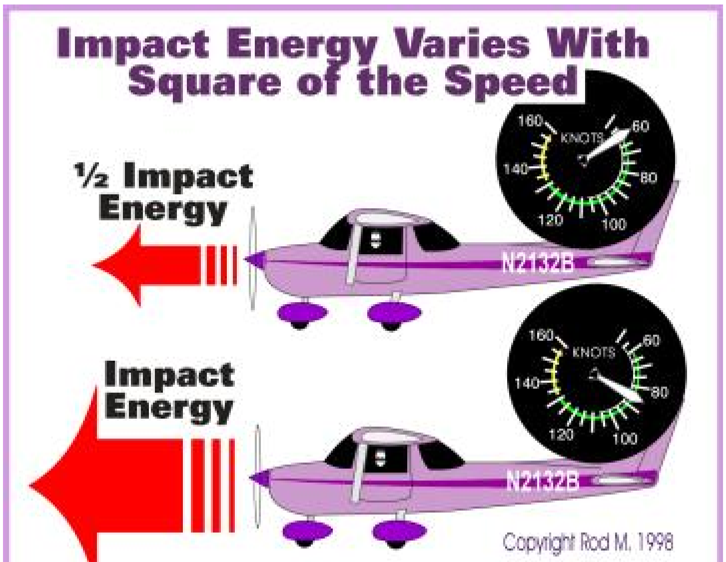

Figure 1

In the event of an engine failure, you typically have several emergency landing options to choose from. Roads and fields are just a few of the opportunities you have to make your own impromptu airport. But suppose a reasonable landing surface isn't available? Suppose you have only *trees, rocks or structures* to choose from? How might you handle an emergency landing under these conditions? As you're about to discover, there is more science than superstition to this process.

High speed collisions require the dissipation of enormous kinetic energy (energy associated with motion). This energy varies with the square of the airplane's speed. Double the speed of impact and you quadruple the amount of energy involved in the crash. Or, think of it this way. Crashing an airplane at 85 knots is twice as hazardous as crashing one at 60 knots (Figure 1). The fact is that speed kills. Knowing how to dissipate energy in a crash is vital to your survival when forced to land in unfavorable terrain.

Let's explore three simple but very important rules regarding how to crash-land an airplane under these conditions. We're concerned about dissipating the kinetic energy and minimizing bodily damage to you and your passengers. The three rules are shown in Figure 2:

Figure 2

Rule number 1 is self explanatory. In an emergency landing situation, groundspeed determines the amount of energy involved in the impact. *You want to do everything possible to touch down at the slowest possible groundspeed* .

Even a small wind can make a big difference in the survivability of a crash landing. For instance, a 12.5 knot wind makes the difference between a 60 knot crash and an 85 knot crash. If I'm approaching at 72.5 knots indicated airspeed and have a 12.5 knot tailwind, my touchdown groundspeed is 85 knots (72.5 + 12.5 = 85). Make a turn into the wind and that 72.5 knot indicated airspeed becomes a 60 knot groundspeed (72.5 - 12.5 = 60). Comparing touchdown speeds of 85 knots to 60 knots, you can see that landing into the wind (instead of landing with it) allows you to reduce the impact energy by 50%. (See Figure 1 again.)

If there was ever a good time to use the groundspeed function of a GPS, it's when you're descending over inhospitable terrain with a failed engine. If you're going to plant the airplane in rough terrain, you might as well do it as slow as possible. *Assuming* you have enough time to do this and *assuming* your GPS has a reasonably quick refresh rate, you can make a 360 over the chosen landing site and monitor groundspeed readings on the way down. The heading with the *lowest groundspeed* should factor heavily into your choice for the final landing direction. Yes, yes, yes, I know, I know. We're talking theory here, but it can be done (and I'd do it, if possible!).

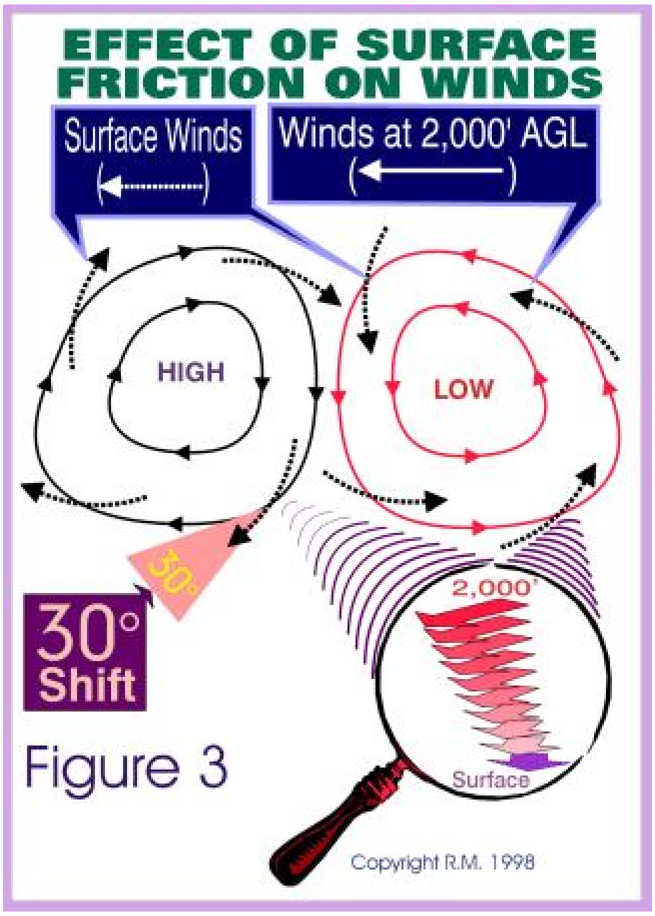

Figure 3

Additionally, keep in mind that surface winds normally shift about 30 degrees to the left from their direction at 2,000 feet above the ground (Figure 3). Therefore, if the wind is from 300 degrees at a few thousand feet above the surface, expect it to blow from *approximately* 270 degrees at the surface. The plain truth here is that it's worth going to all that trouble to know the wind direction when it's not obviously apparent. Even a few knots can make a very big difference.

Applying flaps also allows you to reduce the airplane's impact speed. Some flaps have more of an aerodynamic effect than others. Cessna's Fowler flaps are very effective in reducing the airplane's stall speed. On the other hand, plain type flaps don't affect the stall speed as much. Nevertheless, it's probably worth deploying them anyway.

One consideration to be wary about with flaps concerns how they affect the airplane's cabin. Figure 4 shows the impact of a Cessna between two trees with flaps deployed. Notice how the flaps penetrate the passenger seating section of the cabin. In this situation, if I elected to use flaps and expected to have the wings absorb the impact, I'd consider having my passengers assume the typical airline crash position. You know the one I mean. It's where you bend over and touch your chest to your legs and grab your ankles. This may prevent passenger injury from flap intrusion into the cockpit. I have a feeling that this position is also very effective for helping digest airline food, which may explain why the flight attendant is always trying to get you to look at the emergency information card after boarding. Humm?

Examine your airplane and take into account flap size, flap position and possible flap movement if the airplane's wings were used to absorb the energy of impact. If you deem full flaps to be a danger to rear seat passengers, you can use partial flaps instead of full flaps during an emergency landing. You're the pilot of your airplane. Decide for yourself what's best for the conditions under which you fly.

Rule number two requires you to arrive at the ground under control. Never, under any circumstance, lose control of your airplane during an emergency landing. For instance, some pilots think that it's better to stall the airplane onto the tops of trees (assuming this is their only choice, of course) rather than fly the airplane directly into the tree tops at slightly above the stall speed. I'd opt for controlled flight into the trees any day. Here's why.

General aviation airplanes are designed to withstand force from the forward direction and from underneath the airplane. If the airplane stalls and rolls inverted (begins to spin) during a tree top landing, the impact energy may be applied to the top of the airplane as you descend through the trees. There's very little structural protection provided by the upper portion of the cockpit of most airplanes. Additionally, seat belts don't work very well in restraining loads applied in the upward direction. Anyone who's ever hit their head on the roof during turbulence knows what I mean. Remember, all bets are off if you can't maintain control of your airplane during an emergency crash landing.

Rule number three requires you to let the airplane and the environment absorb the energy of impact. The fact is that the human body is pretty resilient. Yet it makes no sense to subject yourself to trauma if you can avoid it. Therefore, our objective is to minimize the amount of G force we're exposed to during an emergency crash landing. We can do this by understanding how impact speed and G force are related.

A pilot traveling at 50 mph who stops in two feet experiences approximately 43G's. The human body can't withstand this amount of force without experiencing severe or fatal injuries. The same pilot traveling at 50 mph who stops in five feet pulls only 17G's. This is easily more survivable than a 43G deceleration. Three feet means the difference between a survivable and nonsurvivable accident.

The secret to surviving a crash is to let the environment slow you down in such a way that breakable parts of your airplane (horizontal stabilizer, gear, propeller, wings, etc.) absorb impact energy. Now you know why returning to the airport after an engine failure from too low an altitude is very risky. If you stalled and spun into the ground at 50 mph, you'd probably stop in less than two feet. In other words, there's probably less than two feet worth of crushable structure ahead of you. You'll pull over 43G's and get a chest implant to boot (the control column).

Personally, if I had a choice to stall into the ground or make a controlled crash into the side of an aluminum warehouse, I'd choose the building. No question about it (assuming, of course, those were the only two choices). Your job is to make sure those *aren't* your only two choices!

Most general aviation airplane cockpits are designed to give each occupant every reasonable chance of escaping serious injury in a minor crash landing under the following assumed conditions. First, seat belts and shoulder harnesses are properly used (more on this in Part 2). Second, the airplane experiences no more than 9G's worth of linear deceleration in the forward direction.

The secret to handling the emergency crash landing is deciding how to keep the deceleration down to 9G's or less. You'll be amazed at how little distance it takes to decelerate without pulling more than 9G's.

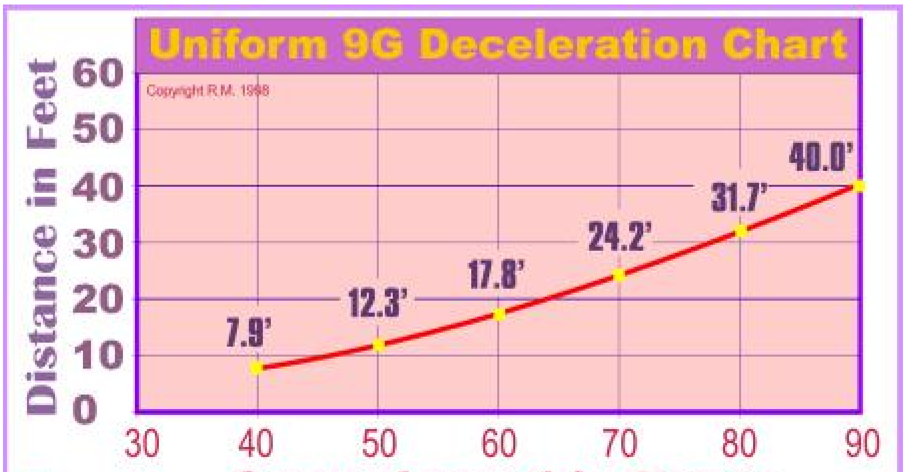

Figure 5

Figure 5 shows the 9G uniform deceleration graph. It provides you with the minimum stopping distance (left vertical axis) versus groundspeed (bottom horizontal axis) necessary to experience no more than 9G's during deceleration. At 50 knots groundspeed, in order to pull no more than 9G's, I need to stop in no less than 12.3 feet. At 60 knots, I need to stop in no less than 17.8 feet. Of course, this assumes uniform deceleration throughout the entire distance, not a sudden stop during the last foot of travel.

Consider the implications of this graph. At 60 knots (a typical groundspeed for most of the airplanes we fly), you need to stop in no less than 17.8 feet (linear deceleration) to keep the cockpit and its occupants relatively intact. That's less than the wing span on most of the airplanes found in the general aviation fleet. Isn't that amazing?

Sure, you may have bruises, blemishes and maybe even broken bones, but, relatively speaking, who cares? Your objective is to avoid serious injury. This is all that matters.

As you can see, there is a science to crashing an airplane. But there's more where this came from. We're not done yet. Next week, we'll talk more about the art of crashing. We'll talk about how to pick and choose those environments that give you the best chance of absorbing the energy of impact. Of course I'm not teaching you to do this for fun, even if you are flying a rental! My objective is to provide you with tools you can use in the unlikely event of such an emergency. Tools are important. As Abraham Maslow once said, “If the only tool you have is a hammer, then everything looks like a nail.”
I had a next door neighbor named Ernie who was 95 years old. One Sunday he invited me over to watch the football game with him. As I sat there he kept yelling at the TV, as if giving instructions to the players. As politely as I could, I said, “Ernie, they can’t hear you.” He grumbled, looked over at me and said, “Oh, that’s right, they got their helmets on.”

Helmets! Now there’s a great idea, especially for a full contact activity like football or emergency landings in inhospitable terrain. Of course, we don’t wear helmets when we fly because it isn’t practical to do so. Engine failures are


Figure 1B


Figure 1A

extremely rare and the ratio of discomfort to protection doesn't justify a helmet's use in general aviation. Besides, if we had to set an airplane down in rough terrain, we have other, more practical means of protecting ourselves during impact.

In Part 1 of this series we discussed three important rules to follow during an emergency landing in unfavorable terrain. Rule number three suggests letting the airplane and the environment absorb the energy of impact. A good rule, indeed. But there's more to this rule than is apparent.


Figure 1C

Figure 1A shows a Baron perched on the side of a mountain near Monterey, California. The pilot was on an IFR flight plan, in the clouds with three passengers onboard. He became distracted, lost navigational awareness, flew up a canyon and came to rest in a grove of trees on the side of a hill (Figure 1B). He didn't plan for this crash at all. In other words, his door wasn't open, seats weren't slid back, the master switch wasn't turned off, etc. Nevertheless, he and his passengers walked away from the airplane with only minor injuries.

Looking carefully at both pictures, you can see that the airplane's structure absorbed the impact very nicely. Nicely enough, that is, to allow the breakup of dispensable structures (wings, engines, tail surfaces, gear, etc.) over a long enough distance, thus preventing excessively high G forces as we discussed last week. Although we can't see the trees behind the airplane, it's reasonable to assume they won't need pruning this season.

If I had to speculate, I'd say the airplane probably experienced around 9 G's during landing. I base my estimates on what appears to be a cockpit starting to disassemble (see last week's article for more info on G-force). Perhaps the majority of cockpit damage is attributable to the rather large tree appearing to the copilot's side of the airplane (Figure 1C). It looks like the airplane came to rest against this tree when its speed had already slowed considerably.

I suspect that an additional factor in the survivability of this crash was the angle at which it occurred. The airplane managed to hit the tree tops at a relatively shallow angle with a low sink rate, which is a perfect configuration when landing on this type of foliage. Of course it's desirable to touch down at the slowest possible speed, with a "zero" sink rate prior to contact. As we mentioned in Part 1 of this series, stalling into the trees isn't a good idea since it can lead to loss of control of the airplane.

The question is: If you had to put an airplane down in unfavorable terrain, how would you choose what to hit and what to avoid? There are two answers to this question. First, under all circumstances, avoid directly hitting anything with the cockpit. Second, if you have to hit something, let the frangible (breakable) parts of the airplane (wings, gear, horizontal stabilizer) do the hitting.

It's obvious that hitting saplings is much better than hitting something on the order of ancient redwoods. This is similar to seeing a big guy whooping a little guy. If you're going to jump in and help, it's much safer to help the big guy whoop the little guy. After all, you have size going for you (I'm just kidding about helping the bigger guy). But I'm not kidding when it comes to trees. In an airplane, go for the little guy, the little trees.

If the foliage is thick, shallow the glide angle and slow the airplane down as you approach the tree canopy. A high angle of attack just prior to contact gives you the additional benefit of protection from the bottom of the fuselage. It also keeps tree branches from directly hitting the windscreen.
If the saplings are spaced farther apart (wider than the width of the fuselage) and don't have much of a crown to them, then there's little benefit from attempting to land on the tree tops. In this case, aim your airplane between the saplings and plan your trajectory to hit closer to the ground.

A military briefing I read once suggested that the bigger the airplane, the lower

Figure 2A

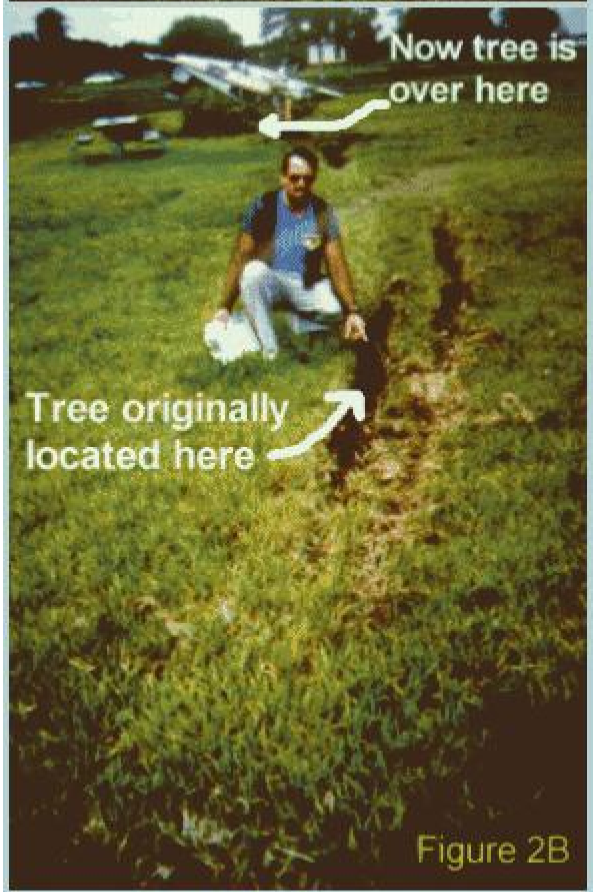

Figure 2B

Figure 2C

Figure 2D

the pilot could hit the tree trunk. The assumption here is that a more massive airplane can afford to hit the thicker portion of a tree trunk since it has more momentum to dissipate. A less massive airplane (like the ones we fly) is better off hitting trees higher up where the trunk or branches are smaller.

Don't, however, contact the trees too high up. The average person can't survive a fall from an altitude of 50 feet or more. Falling from 50 feet is like falling from a four story window. Hitting trees at the 50 foot level or higher may result in serious or fatal injuries.

Additionally, try making your contact with trees (any size tree) symmetrical. In other words, both wings should absorb energy equally. This becomes even more important when the tree trunks are bigger.

Figure 2A shows an emergency landing made by James Stone and his wife D'Ann in their Cherokee 140. An exhaust valve stem failure resulted in a power loss when they were over the Everglades National Park. James descended for a final approach over a mangrove hammock at the west end of a grassy field. As he got closer he recognized multiple picnic tables and grills that were scattered in his planned landing area (sometimes you can only see these things close up).

He chose to miss the steel based tables and barbecue grills (good choice) and aimed his aircraft between two palm trees. Both main tires were on the ground when he hit one palm tree with the left wing. Figure 2B shows Jim pointing to where the tree was originally located. Figure 2C shows the approximate size of the tree Jim hit (notice the circular indentation on the wing). The wing severed from the airplane (Figure 2D) and the airplane rolled over on its back. As the airplane slid to a stop inverted, it came to rest in such a way that it jammed the passenger door (there's only one passenger door on a Cherokee 140).

Jim had to kick out the pilot's window to provide an exit for himself and his wife. They walked away with only small bruises. As I understand it, a fellow camper arrived on the scene, saw James and his wife and asked, "Hey, how did you folks get here so fast?" I believe Jim said, "Ahh, we flew in." You've gotta keep your sense of humor in these conditions.

Several lessons are apparent from Jim's accident. First, things look different from the air than they do from the ground. The next time you happen to drive by a grove of trees, imagine what these trees look like from the air. Examine the tree canopy, tree density and trunk width, and then imagine the outcome of impacting them during an emergency landing. Develop an idea about what is or is not acceptable foliage upon which to make an emergency landing.

Second, contacting an object with only one wing may cause the airplane to roll inverted. This could prevent easy egress. Nevertheless, it's good to know that the average person, if motivated, can kick out a single-pane window if the exit door is blocked.

Third, there's a hidden lesson in the way the airplane's kinetic (movement) energy dissipates when one wing strikes a tree.

Striking a tree with one wing typically causes the airplane to roll about its vertical axis (yaw) or about its longitudinal axis (roll) or both axes. No doubt that Jim chose wisely in hitting a tree with one wing rather than striking it head on with the cockpit. Why? Rolling helps dissipate the airplane's kinetic energy. This is a very important concept to understand.

If you ever get a chance to watch movie stunt drivers, notice how they carefully plan the impact of their automobiles. They always strive for the *glancing blow* while avoiding head on collisions. Hitting an object with the side of a vehicle (the wing, in the case of an airplane) prevents sudden stoppage and sets up a rolling or spinning type motion. This allows more parts of the vehicle to absorb the impact energy. In the case of a car, all four fenders, doors and engine help absorb this energy. An airplane uses its wings, horizontal stabilizer, gear and engine to so the same.

In September of 1983 my friend Danny Mortensen crashed a Rutan racer after an encounter with wake turbulence while racing at Reno. The turbulence rolled Dan's airplane inverted causing it to strike the ground *cartwheel-like* at over 200 mph and roll several hundred feet. Dan walked away from this crash with only scratches to his fingers. There wasn't one person in the crowd who thought he was still alive.

What saved Dan was the rolling (cartwheel) motion of his airplane. Rolling allowed the airplane's wings, engine and gear to absorb the impact energy. He had the additional benefit of being in one of Burt Rutan's composite airplanes--a very strong aircraft. Additionally, he wore a helmet and had a multiple-strap seat restraining device.

My friend Dean Engelhardt was a professional movie stunt pilot. He's crashed over 14 airplanes on purpose. His secret is to avoid head on strikes with the airplane he's flying. In preparation for a spectacular crash in a Cessna 206, he put the airplane in a forward slip and hit the ground left wing first. This sets up a rolling, cartwheel-like motion which helped dissipate the energy of impact. The wings, horizontal stabilizer and engine were destroyed in the process while leaving the cockpit relatively in tact. Dean says that most crashes culminating with a cartwheel-like motion versus a head-on type impact typically result in less than serious or fatal injuries.

What's the point here? Am I telling you this because I want you to do exactly what Dean did in crashing the 206? Not really. Neither you nor I am qualified to do such a thing, even if the airplane is a rental. We're better off letting the environment (trees, fixed structures, etc.) absorb the energy of impact. If it looks like a direct collision with an obstacle is likely, then use the *glancing blow* concept. Avoid a head-on strike. Try to hit the obstacle with the side (the wing) of your airplane like Jim did. This is they key to minimizing injury when making an emergency landing in inhospitable terrain.

In Part 3 of our series, we'll continue our investigation into preparing for the crash landing. Remember, the information contained in these articles is meant to help prepare you for those very, very rare events when you're forced to land in inhospitable terrain.

In-flight Emergencies - Part 2

Minimizing the Chance of a Postcrash Fire

My neighbor Ed was a serious smoker, at least until he accidentally placed a lit cigarette in his jacket pocket and set himself on fire. I heard the commotion next door and ran over to witness Ed jumping up and down on his smoldering jacket. I said "Nice jacket. Is it a *blazer*?" With minor burns to his arms, he was in no mood for humor.

Yes, it's hard to find anything funny to laugh about when talking about fire. It's a very dangerous thing. It's even more dangerous when it occurs after an airplane crash. Therefore, pilots need to know something about minimizing the chance of a postcrash fire when making an emergency landing.

Postcrash fire is a major concern when the possibility of a high-G impact exists. A *fuel source* (typically a ruptured fuel tank) and an *ignition source* are the two

Figure 1

ingredients necessary for the start of a fire (the presence of oxygen is assumed). For all practical purposes, your only control over the source of fuel is shutting off fuel valves and deactivating electric fuel pumps prior to impact. Ruptured fuel tanks are a possibility, but their occurrence in these situations is often beyond your control. You do, however, have more control over reducing or eliminating the source of ignition.

There are two common sources of ignition in postcrash fires: *electrical spark* and a *residual heat source*. Electrical spark can virtually be eliminated by turning off the master switch (Figure 1) prior to impact. Remember, most fuel tanks are in the wing where the nav and strobe light circuitry is located. Eliminating this circuitry as an ignition source will surely help minimize the potential of a postcrash fire.

Unfortunately, our general aviation airplanes don't have *inertially-deactivated* master switches. The advantage of such a switch is that it would automatically shut off the electrical system during a high-G impact. We do have an ELT with a 5-G *impact-activated* switch. So why not a 5-G deactivated master switch to help minimize the chance of a postcrash fire? Hmmm.

Depending on the airplane, you may want to avoid shutting off the master switch until the last possible moment prior to impact. Remember, you may need to lower electrically operated gear or flaps or make radio calls and keep the transponder operative prior to landing.

The second source of ignition for a postcrash fire is *residual heat.* Hot exhaust stacks are a typical source of residual heat (Figure 2). Fuel from a ruptured tank pouring over such a heat source might easily ignite (depending on the source's temperature, of course). Hardly any information exists regarding residual heat

sources and their ignition potential for general aviation airplanes. You might, however, find the following information useful. During World War II, the military did a study on the postcrash fire potential in P-47's and Corsairs. Like most general aviation airplanes, the P-47 and Corsair have aircooled engines. The military discovered that the chances of a postcrash fire ignited by the failed engine's residual heat could be reduced by approximately 90% if the airplane had a chance to glide for at least 20 seconds before impact.

If I may take a little liberty to speculate, consider that the engines on a P-47 or a Corsair have more mass than the typical general aviation engine. Therefore, they probably retain their residual heat longer than do most smaller engines. It's reasonable to speculate that, in obtaining the same percentage reduction of postcrash fires caused by residual heat, a general aviation airplane may need less than 20 seconds of cooling before impact. This is only speculation on my part. Additionally, this suggests opening the cowl flaps (Figure 3) as part of the engine failure checklist (unless your POH states otherwise). After all, this does provide better engine cooling.

Consider the implications of this information if an engine fails on takeoff. Let's assume your engine quits on takeoff at 500 feet AGL. If, at the best glide speed, your airplane descends at 500 feet per minute, you have at most one minute before touchdown. This suggests adequate cooling time to prevent the ignition of fuel by a residual heat source.

But what if an engine fails on takeoff and you attempt a return to the airport at too low an altitude? No doubt that a spin on takeoff substantially increases your descent rate. It also increases the possibility of a ruptured fuel tank and the chance of a residual heat source remaining hot enough to ignite fuel. Need I say more? This is good enough reason to know the minimum altitude required for a turn-back before ever attempting such a thing.

The lesson provided here is for that rare occasion when it's necessary to set an airplane down in inhospitable terrain. Ensuring that the master switch is off prior to impact is the key to minimizing a postcrash fire. Make it a point to avoid flying over terrain that could result in a high-G impact during an emergency landing. Remember, you have a choice as to where you fly. Make sure you choose wisely.

In Part 4 of this series, we'll continue our investigation into preparing for the crash landing.

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Figure 1

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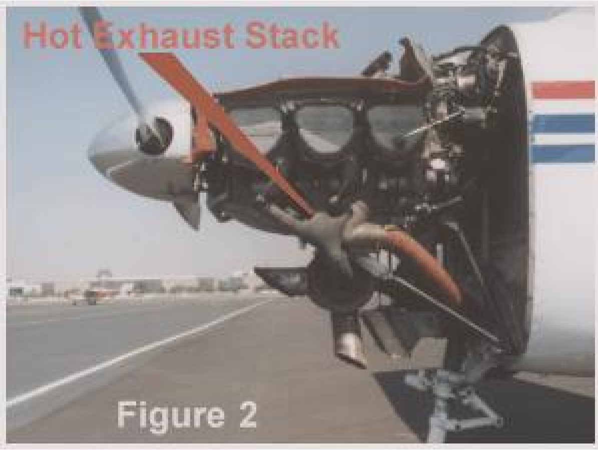

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Exiting a Damaged Airplane

As a professional speaker I always inform my audience that, in the event of a fire, they should follow me out one of the marked exit doors. Of course, I jest (a little). The fact is that knowing how to exit a place of danger is very important. Especially when that place is an airplane that has just completed an emergency forced landing.

Most emergency landings present little or no problem for pilot and passenger egress. But what happens if you're faced with a landing in inhospitable terrain that damages the airplane or flips it upside down? How would you exit an airplane if bent wings prevent the door from opening? What if the airplane rolls inverted and prevents the only exit door from opening? Let's take a closer look at these problems.

Your ability to exit a damaged airplane is an important safety consideration. After all, despite our discussion on reducing postcrash fires, they can still occur. Thus, getting out and away from the airplane after a crash is always a good idea. This is one of the reasons I recommend that you pop open one or more exit doors before making the emergency landing. Once open, you should wedge something between the door and the airframe to prevent the door from closing during impact. An unused jacket, sectional chart, or hat is often readily available for wedging purposes.

It's been suggested by some that opening a door prior to impact may reduce the airplane's structural integrity. This is a reasonable point since crash tests on airplanes (for structural integrity purposes) are usually done with the doors shut, not open. But is the increase in structural integrity worth the increased risk of a

door jammed shut by the impact? I suspect it's not, although the risk certainly varies with the type of airplane and the manner in which the cockpit is constructed.

It's still possible that an emergency landing in inhospitable terrain might result in airframe damage which could prevent the airplane's doors from opening. Figure 1 shows a Cessna that flew up a blind canyon (a one way canyon) and crashed on the side of a hill. Notice that the left wing was twisted on impact, preventing the pilot's door from opening. The passenger's door, however, was usable for egress.

Bent or twisted wings present a problem both for high and low wing airplanes. If the airplane has only one exit door (like most single-engine Piper products) then egress may become difficult if that door is blocked. Fortunately, there is another means of escape that few pilots (and passengers as well) consider: baggage compartment doors.

Baggage compartment doors are often latched with very weak locking mechanisms. In many cases, one good kick will pop most of them right open. Some airplanes, like Mooneys, even have pullable pins which allow you to open baggage compartment doors from the inside.

Several years ago a young lady named Dara wrote to tell me of her involvement in a crash of a Grumman American Tiger (a four place airplane with a sliding canopy). She was in the rear seat while two others occupied the front seats. The engine failed on takeoff and the resultant hard landing started a fire (the master switch was not turned off and engine's heat probably ignited leaking fuel).

The right seater escaped by sliding the canopy rearward while the pilot was semi-conscious and remained in the left seat. Fire prevented Dara from exiting through the canopy and over the wings. Though not a pilot, she had attended one of my In-flight Emergency seminars and knew what to do. She climbed over the rear seat and kicked out the baggage door for egress. Dara is a petite lady, perhaps weighing no more than 100 pounds. The pilot regained his faculties and managed to escape despite serious burns. The point here is that the baggage compartment is a viable means of escaping an airplane. It's even more relevant in this instance since it leads to an exit away from the wings which commenced to burn.

Of course, making your way to the baggage compartment becomes difficult when you have to climb over seats and baggage to get to it. This is a good reason to test the feasibility of exiting the airplane through the baggage compartment while parked on the ramp. Of course, since it's not a real emergency you shouldn't kick the door open (even if it is a rental). Just climb over the front and back seats and assess the difficulty of exiting this way.

Additionally, if your airplane has a baggage net between the rear seats and the


Figure 2A Airplane resting on exit door

baggage area, it should have quick-disconnect clamps for easy removal in an emergency. Nothing worse than a net preventing your escape. (Can you imagine how those dolphin feel when they become trapped with their tuna buddies? Of course, if those dolphin are so smart, why are they hanging out with tuna in the first place?)

An airplane that rolls inverted during an emergency landing presents another serious problem for egress. Suppose your airplane has only one exit door, like the Cherokee 140. If the airplane comes to rest inverted and on its side, the exit door may be blocked. A few weeks ago I showed you a picture of Jim Stone's airplane that did exactly the same thing after it clipped a tree and lost a wing (Figure 2). Fortunately, Jim kicked out the side window which made for an easy escape.


Figure 3

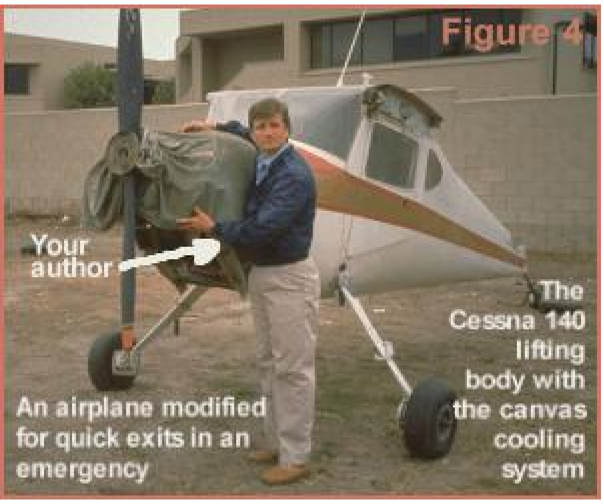
Remember, airplanes like the Cherokee 140 have double latching mechanisms. One latch is located on the door handle; the other is located on top of the door. An inverted airplane coming to rest on the upper door latch might render that latch inoperable. All the more reason to open the door prior to impact, especially when it's the airplane's only exit door.

My friend Don Bymaster, who teaches the pilot proficiency program for the Mooney Safety Foundation, offers some good advice in these situations. Don recommends that, in an inverted airplane, your quickest means of egress isn't necessarily through the Mooney's single entrance and exit door. He suggests bracing yourself and kicking out a side window. Often, this offers a much easier and quicker means of exiting the airplane. This recommendation is part of all his passenger safety briefings. I believe this is good advice for most airplanes (assuming that they aren't pressurized airplanes, of course. Pressurized airplanes have much stronger and beefier windows that are undoubtedly more difficult to dislodge, unless, of course, you kick like Bruce Lee).

What if you're flying a canopy-type airplane (Figure 3) and it rolls inverted? In my opinion, this is a very serious problem. Canopies on airplanes like the Katana, AA-1 Yankee, Tigers, etc., don't provide a great deal of supportive structure in the event the airplane lands inverted. It's possible that the canopy may crush and crumble making normal egress through the canopy difficult if not impossible. It's not a problem if the airplane has an accessible baggage compartment. But what if it doesn't? Well, you're going to love this bit of advice.

If you're flying a canopy-type airplane without a baggage compartment for egress, I recommend that you carry a tool for cutting or breaking Plexiglas (nope, I'm not kidding). Suppose your canopy-type airplane rolled inverted during an emergency landing. Unless you have some means of cutting through Plexiglas, you're not getting out until the firemen arrive with the appropriate tools to liberate you. Why wait? Carry your own tools.

A good hatchet is my tool of choice. A small saw-type cutting tool capable of cutting into and slicing through Plexiglas is another acceptable choice. Don't think that you can cut through Plexiglas with a small pocket knife or that you can shatter the Plexiglas with a good punch or kick. You may eat your spinach and asparagus and be big and strong, but Plexiglas is designed to flex. It's unlikely that you'll be able to break Plexiglas with your hand or foot. (Last week when I talked about kicking out a window, I meant kicking it out of its mountings, not breaking the plastic).



This advice may seem a little unusual, but it's good advice nevertheless. Of course, if I carried any sharp object in the airplane I'd do so in a way that wouldn't cut, hurt, wound or intimidate anyone. Be smart, carry the hatchet or saw-knife in a pouch and tuck it away somewhere. Don't wear it in a holster around your belt during preflight and, whatever you do, don't mumble to yourself while you're holding it. No one will fly with you and line personnel won't service your airplane.

Remember, these are recommendations and should never supersede the information in your Pilots Operating Handbook. Additionally, whether the airplane is high or low wing, rigid or plastic canopy, tailwheel or tricycle gear, is irrelevant in terms of in-flight safety. One airplane is not necessarily more safe than another. The key to safety is in how you prepare to fly the airplane. Of course, if you have an airplane like the one in Figure 4, you never need to worry about the wings blocking an exit during an emergency landing in inhospitable terrain. In fact, you never need worry about exiting the airplane because no one in their right mind would get in this thing.

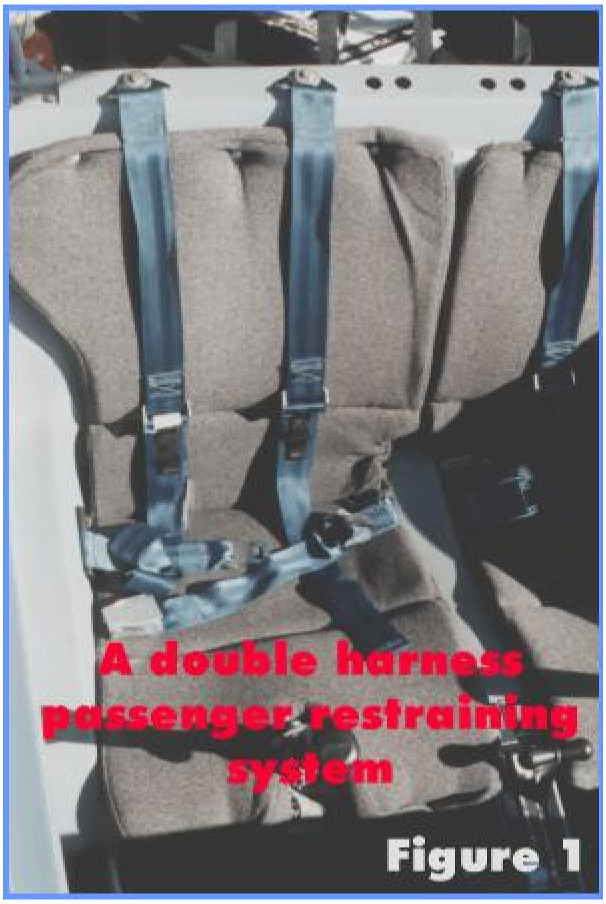
In the final Part of this series we'll cover a few more points to help you in the event an emergency landing is necessary in inhospitable terrain.

A Few More Things to do Before the Emergency Landing

By Rod Machado

Few people like to think about the unthinkable. Our local newspaper just reported that in the year 2028 a large asteroid may strike the Earth, delivering megatons of energy to our doorsteps. This isn't a comforting thought, but it is a good reason to consider buying that RV you've been thinking about. After all, it's hard to hit a moving target.

The unthinkable is the focus of this series on in-flight emergencies. Setting an airplane down in inhospitable terrain is, indeed, a very rare event. Yet, we can prepare for the event for no other purpose than finding comfort in the knowledge that we have a plan in case the unthinkable occurs. Here are a few additional thoughts to consider in case an engine fails over rugged terrain.



Occupant Restraining System

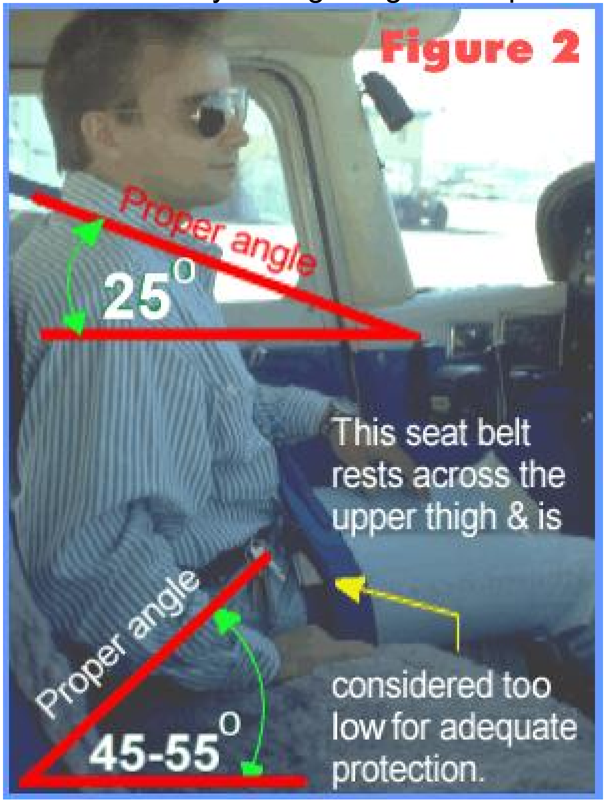
As you'll soon discover, I am a big fan of seat belts and shoulder harnesses. I wear them whenever I'm in anything that moves. And, if my bed had them, I'd wear them at night since I live in the earthquake capital of the world+California. Why the fanaticism?

Many years ago an FAA friend showed me pictures of several crashed airplanes and asked me to speculate about how the occupants faired after the impact. He slipped me a picture of a Belanca Viking that didn't look too badly damaged. I said, "Hmmm, no fatalities on this one." Wrong! The right seat and back seat passengers died. The pilot, who was wearing a seat belt and shoulder harness, lived. Then he showed me a picture of an A-36 Bonanza that was almost flat as a pancake, its cockpit nearly destroyed. I said, "No way anyone could survive that." Wrong again. Both pilot and passenger survived because they both wore seat belts and shoulder harnesses.

The fact is that your biggest ally in surviving a crash landing is the airplane's *passenger restraining system* . Here's what you'd order if you had your choice of a good restraining system.

First, you'd order a double shoulder harness (Figure 1) with a lower body restraining system (belts that wrap around the inside of your thighs). A lower body restraint keeps you from sinking and sliding under the lap belt during sudden stops. You'd also choose belt webbing at least .09 inch thick, preferably constructed from Dacron vs. Nylon (Dacron stretches a lot more under a given load).

Second, the strap over the shoulder should make an angle of approximately 25 degrees with the horizontal as shown in Figure 2. Angles less than 25 degrees may cause spinal compression as the pilot's body moves forward and under the shoulder harness. Strap angles greater than 25 degrees with the horizontal may not provide the restraint necessary during a high-G stop.



Third, the angle of the seat belt should be approximately 45 to 50 degrees as shown in Figure 2. Additionally, these belts should lie across your hips, not your upper thighs nor your lower abdomen. If the hips aren't restrained in a crash, your body could slide under the belt, causing abdominal or spinal injuries. This is the reason that inner thigh restraints are very helpful in a crash. Seat belts resting above the hips might not restrict the forward movement of your body in a crash.

Figure 3 will make you a real believer in shoulder harnesses. Column A identifies accidents where the cabin was distorted but remained intact (representing 68% [a total of 1,069 occupants] of the accidents studied). These accidents resulted in 210 occupants suffering serious injuries and 143 suffering fatal injuries. The FAA said that shoulder harnesses would have *prevented all these serious and fatal injuries* .

Column B identifies those accidents where the cabin was partially collapsed (representing 24% [a total of 379 occupants] of the accidents studied). These accidents resulted in 90 occupants suffering serious injuries and 155 suffering fatal injuries. According to FAA information, shoulder harnesses would have *reduced these serious and fatal injuries by 50%* .

Injury Severity

	A	B	C
Percentage of Total Accidents:	68%	24%	8%
Cabin damage:	Distorted intact	Partially collapsed	Demolished
Occupants:	1,069	379	124
Injured seriously	210*	90**	17
Injured fatally	143*	155**	87

* Shoulder harness would have prevented
** Shoulder harness would have reduced by 50%

Source: FAA

Figure 3

Seat Position Before the Crash

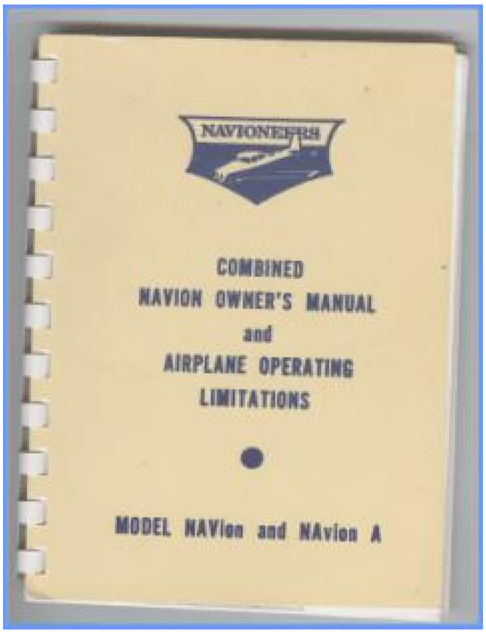
Seating position is another important factor in crash survivability. As we discussed in Part 1 of this series, stopping distance is the key to preventing injuries. The typical cropduster has approximately eight to ten feet of distance between the pilot's seat and the tip of the airplane's nose. That's an extra eight to ten feet of distance in which to decelerate the airplane's occupants. If a pilot only needs 12.3 feet for a 9-G deceleration, then eight feet of crushable nose area give the pilot 65% of that distance.

Many light twins have similar distances between pilot seats and the tip of the airplane's nose. Smaller training airplanes, however, can have only four to six feet of distance between pilot seating positions and the airplane's nose. What does all this mean to you?

It means that you may gain a slight advantage in survivability by increasing the distance between you and the airplane's nose. You and your passengers would do this by moving your seats as far aft as is practical. In most smaller airplanes you can gain nearly a foot to a foot-and-a-half advantage in distance by sliding the seat back.

In some cases this is more practical for the front seat passenger than it is for the pilot. After all, the pilot must still fly the airplane. If the pilot is short, he or she needs to remain close enough to manipulate the flight controls. Taller pilots can easily slide the seats aft before impact (if they're not already against their aft stops).

Passengers should also place something protective over their face prior to impact. A jacket works well in these instances. This tends to be more difficult for the pilot to do since he or she still needs to fly the airplane. But, where possible, pilots should do the same prior to impact.



Gear Up or Down?

Whether the gear should be up or down during an emergency forced landing in inhospitable terrain has always been a point of contention among pilots. Detailed advice on whether the gear should be up or down is suspiciously absent from almost all Pilot Operating Handbooks (POH) that I've seen. In fact, most POH's state only the following in regards to gear extension during an emergency landing:

"Landing Gear - up or down (depending on terrain)."

Huh? Could we be a little more vague about that?

The Navion owner's manual provides the most extensive advice I've ever seen written on the subject in any POH. It reads:

"If the landing area selected appears relatively smooth ... lower the landing gear. If there are any indications of stumps, ditches or rough or muddy ground, keep the gear up. There is less chance of injury in making a belly landing."

As you can see, this isn't very extensive advice on the subject. Nevertheless, it's the best there is (for this particular airplane). So, let's consider these points in gear use during an emergency landing.

First, if the surface is hard (dirt, sod, asphalt, concrete, etc.) it makes sense to land with the gear down. If the surface is soft enough to cause the wheels to catch, possibly flipping the airplane over, then land with the gear up. Surfaces like water, mud and swampland could easily cause the airplane's nose to dig in and flip the airplane if the gear were extended.

Second, consider the advantages of extended gear when forced to land in the tree tops. The landing gear becomes a breakable impact-absorbing structure which may help retard forward motion through branches. Additionally, depending on the type of gear, it may offer better deceleration in the vertical direction.

There are concerns, however, about crashing airplanes with the gear down. It's possible that the gear could tear into a fuel tank as it rips away during impact, leading to a fire. This is more of a concern for low-wing airplanes than it is for those with high wings. Also, during impact, the gear might enter the cabin and injure the passengers. Finally, on some airplanes, part of the gear lies directly underneath or ahead of the fuel tanks. Thus the gear may provide a barrier of sorts to minimize the chance of fuel tank puncture. How do you know if this is true for your airplane? You don't, unless you ask. Find a competent mechanic and ask him or her about the gear and fuel tank structure or call the airplane manufacturer for help with this information.

Whatever you learn or decide about gear-up or gear-down landings, you can take solace in a study done many years ago by the USAF Flight Safety Research Branch. This study indicated that, in any sort of terrain, forced landings in tricycle-geared airplanes are less likely to result in injuries or fatalities if the landing gear is down.

Choice of Fields

Appearance	Desirability
Runway	
Watch for hard surface runways or private dirt/sod strips on farm or desert land which are usually near a house or work	What can I say? These are the places airplanes should land.
Roads and Highways	
You know what these look like!	Use caution on dirt roads in isolated areas. They may be badly eroded. Also, use caution for power lines near rural roads.
Stubble field	
Light straw color on visible ground. No motion in wind.	Usually good. Avoid fields with contours and unusual growth patterns.
Plowed fields	
Dark brown or black. Large furrows.	Not good, especially with gear down. Land with the furrows if the wind allows.
Growing vegetation	
Green. Casts shadows. Motion in wind.	Possibly workers in field. Thick growth may snag wheels of light plane. Avoid extra dark or light spots or strips. They may conceal rocks or ditches. Land with furrows.
Pasture	
Irregular light green and light brown. Contours usually visible. Animals. Usually had stock tank or pond.	If it were level and free of large stones, it would have been plowed. Best to avoid if possible. (Besides, may hit cow causing it to give sour milk.)
Sand	
Beach at water's edge, sandbars in river.	If the edge of the water is straight, the sand will be level. Pick dark (damp) sand if possible.
Dry lakes	
White.	In desert country, very good. Behind dam, may be filled with rocks and old stumps!

Figure 4

Source: NTSB Special Study, Emergency Landing Techniques, Fixed Wing Aircraft, April 5, 1972

Landing Site Selection

Throughout this series we've assumed that our landing site is in unfavorable terrain. Mountainous areas, trees and boulder-strewn fields all qualify in this category. Of course, your job is to avoid those areas that diminish the chances of making a successful emergency landing. One way of avoiding these areas is by staying home and wedging yourself between two big mattresses. But what fun would that be? Therefore, let's examine a few more ideas regarding preferable places to land.

Figure 4 shows possible landing sites, their appearance from the air and their desirability for landing use. While this list is anything but complete, it does provide you with a start for assessing the desirability of a landing site. It's also possible that the only reasonable field in which to land is too short. What do you do then?

Sometimes it's preferable to attempt a landing in a confined area that's free of obstructions instead of attempting to land in an area with scattered obstacles. Once again, there are no hard and fast rules here. Each case must be assessed individually.

Approach the problem this way. The next time you land, make it a short field landing. Since runway lights are spaced at 200 foot intervals, make a rough estimate of your stopping distance while taking the headwind into account. In Cessna 172's, for example, it takes about 550 feet of ground roll to bring the airplane to a stop. To clear a 50 foot obstacle and stop, it takes a total distance of approximately 1,200 feet. These figures are typical for gross weight conditions at sea level.

Now compare that to the length of a football field, which is approximately 300 feet long. Football fields are rather common and are easily seen from the air. This gives you a good measure by which to estimate the length of a field while airborne. Ask yourself, "Could I get this airplane down and stopped in the length of a football field?" The answer is, "Yes, you can, as long as you have a few other tricks in your bag to work with."

The above mentioned short field distances are based on an approach speed of 30% to 40% above stall speed (the typical speed most POH's recommend for short field approaches). But who says that you must approach at 30% to 40% above stall speed when trying to get the airplane down in a confined space in an emergency?

I've known pilots to use values of 10% to 20% above stall speed for short field approaches. Of course, they have power if they need it and they are quite cognizant of operations on the back side of the power curve. Nevertheless, in an emergency, if you had to get an airplane down in a confined area, and you were skilled at airspeed control, it's perfectly reasonable to make an approach with a much lower short field approach speed. Remember, we're talking about an emergency here, not normal flight conditions. The lower approach speeds should dramatically decrease your obstacle clearance and landing roll distances.

Sometimes, it may be wise to force the airplane down onto the ground if a collision looks imminent. Considering this circumstance, raising the flaps on touchdown or even during the flare is another reasonable action. Perhaps you may even retract the gear after touching down as a deceleration aid.

Ground looping the airplane is another option if it's necessary to stop in a short distance. I am, however, always concerned about an airplane flipping inverted during a ground loop. As we discussed last week, an inverted airplane may present difficulty during egress. All these variables must be taken into account in an emergency.

Let's consider one more point on selecting landing sites. I've heard pilots talk about forcing an airplane down in a lake in mountainous terrain where there are no other reasonable landing sites available. We will consider *water ditching* in a future article but, for now, understand that landing in water isn't much softer than landing on solid ground. Anyone who's done a belly flop off a diving board knows this. If you forced an airplane down into a small lake, and survived, ask yourself how long you'd live in the typical freezing water of high mountain lakes. Hypothermia is a killer.

Your biggest concern with forcing an airplane down in a small lake vs. a similar size land mass isn't with hypothermia. Rather, you are mainly concerned with being knocked unconscious by the impact and drowning. As you'll see in a future article, most airplanes don't float for long. If you're knocked unconscious during a water landing, your chances of survival are very poor (remember, we're talking about *forcing* an airplane into a short body of water). On the other hand, and relatively speaking, being knocked unconscious on land isn't all that bad as long as there is no postcrash fire.

The odds that you'll ever need to apply any of the information contained in this series of articles are miniscule. I present this information to you because it's simply comforting to know that there are answers to some of the very difficult problems on which we speculate when sitting around the flight school. I wish I could lead you to more literature on how to handle emergency landings in inhospitable terrain. Unfortunately, there isn't a lot of information available on this subject, and that was written by Mick Wilson. I've listed it below.

1. Mick Wilson, a retired FAA inspector and crash researcher has a book titled "How to Crash an Airplane." Information can be found by e-mailing Mick at: mwilson@crashandsurvive.com .
2. The following NTSB Report Number - AAS-72-03 , Adopted on 04/05/1972 . Order NTIS Report Number - PB-209836 . Title: *Emergency Landing Techniques in Small General Aviation Fixed Wing Aircraft* is a very informative report. You can locate this information at: http://www.ntsb.gov/Publictn/A_Stu.htm

This is the end of the five part series on handling the emergency landing in inhospitable terrain. Look for another series of articles on in-flight emergencies which will cover topics such as electrical and petroleum based in-flight fires, gear-up landings, flight control failure, flutter, propeller fracture and much more. Remember, the idea isn't to be scared; it's to be prepared.