Ethical Issues from the Panama Canal Failure

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CONTENTS

1. INTRODUCTION

There is only one Panama Canal. But there are two Panama Canal stories. One is about the successful construction of the Panama Canal by the United States. The other is about an earlier failed attempt by French interests.

This is the story of the failed French attempt to build a Panama Canal. It is a story with timeless ethical lessons for engineers….and public and private policy makers….from which to learn. This is a story that unfolded between1879 and 1889. But the ethical lessons are as relevant today as they were then. First, some background….

There are four facets to the failed French attempt to build a Panama Canal. They are:

- Health safety
- Financial
- Political
- Engineering

The health safety issues were critical to the ultimate successful construction of a Panama canal by the United States. The Panama Canal was constructed in a tropical region of central America where often-fatal diseases such as malaria and yellow fever were a constant threat to those working on the project. There were tens of thousands of deaths on both the French and U.S. projects. Ultimately U.S. public health officials were able to develop strategies to neutralize the threats posed by these diseases. The health safety issues are part of the Panama canal saga, but they are not part of this discussion.

The French and U.S. Panama canal projects were both hugely expensive undertakings. The two countries, however, took different approaches to financing their efforts. The French raised the majority of their funding in the capital markets from private investors, many of them small individual investors, through stock sales and similar financial devices. The United States took a different approach. The United States appropriated funds for its effort through Congressional and Executive Branch action, that is, through taxation of American citizens. Although this is not an examination of the funding mechanisms used by the two countries, a legitimate question is raised whether the financial pressures on the leaders of the French project to return a profit to their private investors led them to the serious lapses of engineering ethics for which they were responsible in their project management.

Political considerations certainly had their role in development of a Panama canal. The late 19th century was a time of great expansion of global trade and commerce. European countries, the U.S. and others were interested in establishing themselves as global leaders in trade. Although many countries suffered from this national ego-building impulse, it would not be unfair to say that French political interests were very interested in seeing France in a leadership, if not controlling, position in development and operation of an Atlantic-to-the-Pacific maritime canal.

This is a story that centers on engineering issues, however there is every appearance that financial and political pressures on the French project leadership drove them to the ethical lapses that resulted in engineering decisions that led to a catastrophic collapse of the French Panama canal project. Let’s look at what happened….

2. WHAT HAPPENED

When the geography of the “new world” was revealed to European colonists….the social, economic and political value of a short-cut from the Atlantic to the Pacific Ocean was obvious. It was a long voyage from Europe to the Orient around Cape Horn, the southern tip of South America. A much shorter route through that sliver of the continental divide that we now call Panama was a very enticing prospect. In the early 19th century a German scientist, Alexander von Humboldt was perhaps the first to articulate a passage from the Atlantic to the Pacific through Central America. Such a passage would reduce a voyage from New York to California from about 13,000 miles around Cape Horn to one of about 6,000 miles through Central America.

There were three route suggested for a canal between the Atlantic and Pacific oceans in the late 1800s: (1) across Panama, which at the time was a province of Columbia; (2) across Nicaragua, and (3) across the isthmus of Tehuantepec in Mexico. There were important political and commercial forces favoring one route or another.

The United States government had undertaken engineering surveys and investigations of all three routes and knowledgeable professional engineers in the United States were generally disposed to favor the Nicaragua route. An important engineering consideration favoring the Nicaragua route was the existence of a natural lake, Lake Nicaragua, which would accommodate a substantial distance of the coast-to-coast route of a canal.

In 1878, with essentially no engineering investigation, French interests obtained through what might be characterized as political influence, an exclusive concession from the government of Columbia to build a canal across the isthmus of Panama. This was known as the “Wyse concession.” The Wyse concession was negotiated by a Frenchman, Lieutenant Lucien Napoleon-Bonaparte Wyse, who was not a professional engineer but was well-connected in French political circles by virtue of being related to….yes, you guessed it….Napoleon Bonaparte. The Wyse concession was an agreement whereby the government of Columbia granted a consortium of French commercial and government interests an exclusive right to construct and operate a maritime canal across the isthmus of Panama for 99 years. The route the canal was to follow was the same as that of the Atlantic-to-Pacific Panama Railroad which was constructed 25 years earlier. The only engineering surveys, investigations and studies that had been undertaken along the proposed route of the canal were those that had been undertaken earlier for construction of the railroad. It goes without saying that engineering surveys and investigations needed for surface construction of a railroad are much different and less comprehensive than those needed for construction of a monumental canal with massive excavation requirements and earth structures. The only investigation of the proposed route of the canal by French interests was an 18-day inspection in the course of which no hydrographic, topographic or soils surveys, studies or investigations were undertaken. It is not unreasonable to say that even the most junior of civil engineers would immediately recognize that the surveys undertaken for construction of the Panama Railroad were wholly inadequate for planning a trans-isthmus maritime canal.

For a variety of reasons the Tehuantepec route was the least favored.

Ostensibly in an attempt to reach an international consensus on the most advantageous route and configuration for a trans-oceanic canal, French commercial and government interests convened an international congress in Paris in 1879. French interests largely controlled the allocation and distribution of delegates to the conference. Twenty two countries were represented at the congress by 136 voting delegates, but of that number 73 were French and less than a quarter were professional engineers. More importantly, a Technical Committee was formed that would essential determine the conclusions of the congress regarding the two primary engineering issues: (a) the most favorable route and (b) whether a sea level canal would be constructed or one that incorporated locks. 52 delegates were appointed to the Technical Committee by the organizers of the congress and more than half were French. The organizers of the congress appointed the Frenchman Ferdinand DeLesseps, the guiding force behind the earlier construction of the Suez Canal, chairman of the Technical Committee.

The question of locks requires some explanation. Contrary to a common misunderstanding, locks were not a consideration because of a difference in sea level between the Atlantic and Pacific sides of the isthmus. Mean sea level is the same on both the Atlantic and Pacific sides. Tides, however, are much more pronounced on the Pacific side. On the Atlantic side of the isthmus the differential between high and low tide is less than 4 feet. On the Pacific side it is between 10 and 20 feet. This tidal fluctuation creates a serious operational challenge for a trans-oceanic canal in Central America. Locks incorporated into a trans-oceanic canal are, and at the time were recognized as, an engineered solution to this issue.

After two weeks of deliberations the French-controlled Technical Committee recommended, and the French-controlled delegates voted in favor of, a sea level canal (i.e. without use of locks) across the isthmus of Panama as the most practicable and preferred route for a trans-oceanic canal based on the Wyse concession. Only 19 of the 73 French delegates were professional engineers….and only one of them had ever set foot in Central America. None of the five French delegates who were members of the prestigious French Society of Engineers voted in favor of the Wyse concession proposal. Since French interests had an exclusive right to construct such a canal across the isthmus of Panama (the "Wyse concession") it was a fait accompli that French interests would control such a canal. A French Panama Canal company was thereupon formed to raise the financing for, and design, construct and operate such a sea level canal. To lead the company the renowned but elderly Frenchman, Ferdinand DeLesseps was appointed its president. DeLesseps had conceived the scheme to construct the Suez Canal and successfully lead its design and construction effort. In 1879, however, Ferdinand DeLesseps was 73 years old.

The French company raised and expended about $5.7 billion (unless otherwise noted, all costs quoted herein are in terms of estimated 2010 U.S. dollars) from private investors and government sources. Construction started in 1882 with a labor force of about 20,000. The enterprise collapsed in 1889 with the work about 40 percent completed and a death toll estimated at 22,000. The assets of the French company were sold to the United States government in 1904 for about $1 billion. The United States then successfully undertook to construct the Panama Canal using a substantially different engineering plan, *utilizing locks,* from that which was the basis for the failed French effort.

The French effort to construct a Panama Canal was a, failure resulting in the loss of thousands of lives and billions of dollars in investors' money.

3. THE ENGINEERING ISSUES

This is a discussion of engineering issues and engineering ethics. It is not a consideration of the health safety, political, and financial issues that arose from this monumental undertaking, except to the extent political and financial pressures led to bad engineering decisions. These are the major engineering issues posed by the consideration of the route and fundamental configuration of a trans-oceanic canal linking the Atlantic and Pacific Oceans:

- **Route.** An engineering undertaking of this magnitude and cost demanded an engineering consideration of alternative routes and configurations for the canal. This means consideration of the Nicaragua and Tehuantepec routes, and consideration of reasonable alternative configurations for the Panama route. An engineering consideration of these alternative routes and configurations required an investigation of the topographic, hydrographic, hydrologic, climatic, geotechnical and seismic conditions existing for each alternative route and configuration. It is clear from the record that the route selected by the French was chosen for political and commercial reasons because it was the one route which the French interests had the exclusive right to exploit.

- **Soil Mechanics.** With regard to a Panama route, enough was known at the time about climatic conditions across the isthmus of Panama to raise a significant concern about the mechanics of soils along the proposed canal route. Specifically, routine torrential seasonal rains were known to result in highly saturated soils along the proposed route of the canal, but there was no consideration….at the time of the recommendation of the French-controlled Paris congress….of the impact this phenomena would have on the construction of the proposed Panama canal. This was to be of great importance.

  A simple geometric calculation illustrates the folly of the French proceeding with excavation work without adequate soils investigations and analysis upon which to base the work. For a sea level canal (no locks) as planned by the French a very formidable challenge was an area called Culebra Hill. The peak of Culebra Hill was 339.5 feet above sea level. The sea level canal planned by the French was to be 29.5 feet deep, which means the depth of excavation required was 369 feet. The French plan was based on the canal being 72 feet wide at the bottom and 90 feet wide at the top, and an assumption that 1:1 side slopes would be adequate for stability. This means the Culebra Hill cut would be about 810 feet wide at the top. In the event, the soil conditions were such that the side slope necessary for stability was 1:4. This meant the top of the Culebra Hill cut would need to be about 3042 feet wide at the top and 3 to 4 times as much excavation work would be required. Similar gross underestimates of excavation work required occurred all along the French route. Although the state of soils engineering knowledge was certainly less in the 1880s than it is today, rudimentary soils sampling and laboratory tests would have revealed the seriousness of these challenges to the excavation work and the need for engineered solutions such as route realignment, retaining walls and other slope stabilization measures. This also would have further highlighted the folly of building a sea level canal. The excavation cross-section ultimately accomplished at Culebra Hill by the United States was 1800 feet wide at the top, and this of course was for a lock-based, not sea level, canal.

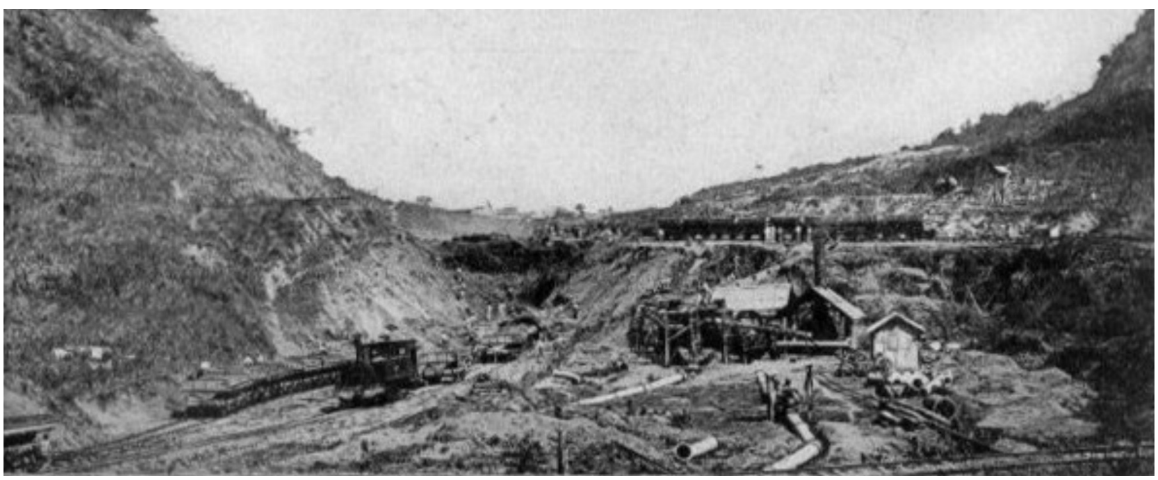

Figure 1
French canal excavation work at Cucaracha, 1885

- **Chagres River Control.** The natural climatology, geography and topography of the isthmus of Panama revealed at the time that any reasonable proposal for a trans-oceanic canal across the isthmus of Panama would encounter the need to transect the Chagres River, which was known to routinely experience extremely high seasonal variations in flow. It was acknowledged at the time that these seasonal variations in flow, unmitigated, would result in unacceptable flow variations in a proposed canal. This transection of the canal route would require monumental hydraulic control structures

The French began their project without any rationale plan for controlling the high flows from the Chagres River which transected the canal route. The ultimate canal configuration constructed by the United States required the construction of two major dams, Gatun and Madden. The Gatun Dam in conjunction with the locks scheme constructed by the United States provided a very creative solution for the canal's ultimate configuration by creating Gatun Lake which provided for almost half the distance of the canal route without the need for much otherwise necessary excavation and engineering works.

Figure 2 shows the Panama Canal as constructed by the United States. Gatun Dam, which formed Gatun Lake (Lago Gatun) is at the upper left near the town of Gatun. Madden Dam was constructed in the 1930s near the town of Moja Pollo at the center-right to form Alajuela Lake (Lago Alajuela) and provide additional storage and control on the Chagres River.

- **Tidal Control.** The significantly higher tidal fluctuations on the Pacific side of the isthmus of Panama presented an important engineering challenge to a Panama canal route. Absent control structures and appropriate operational procedures, these tidal fluctuations presented significant challenges to effective operation of the proposed trans-oceanic canal across the isthmus of Panama. This engineering issue clearly called for a canal which incorporated locks.

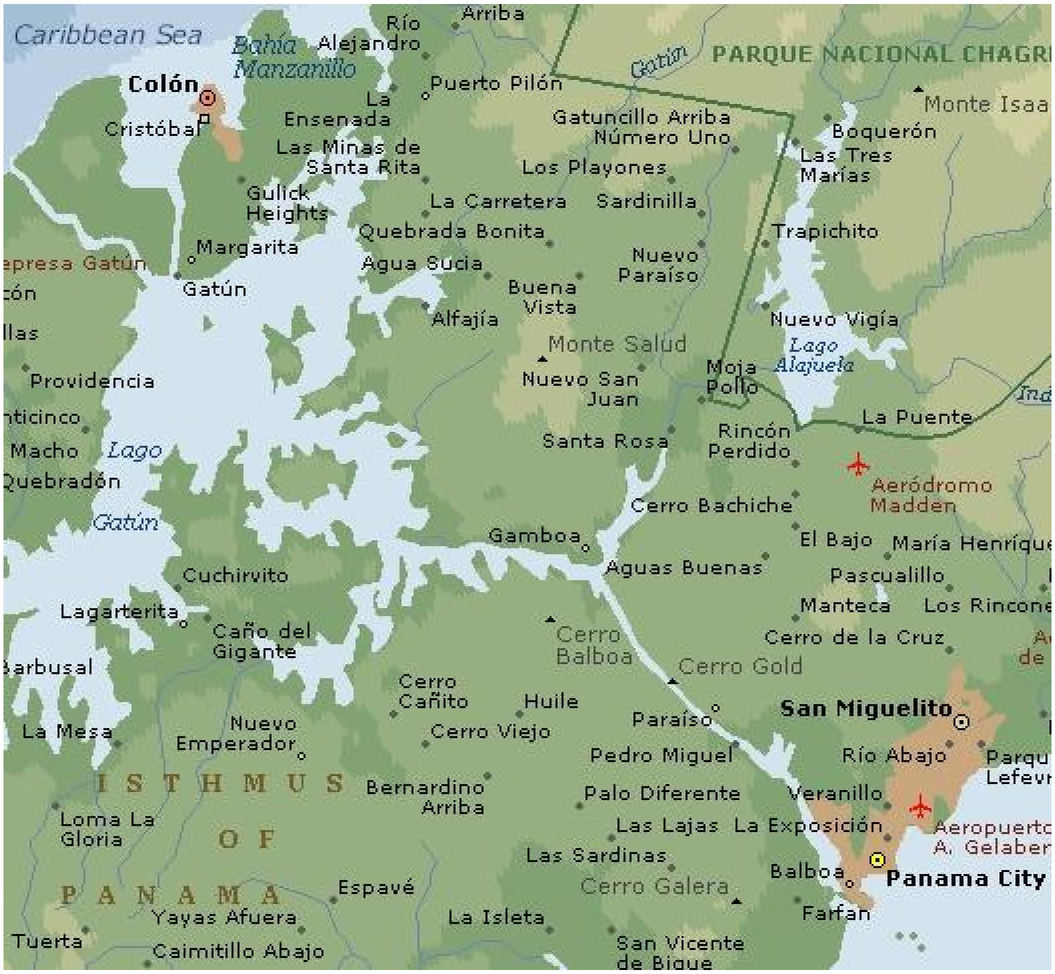

Figure 2

4. THE HUMAN FACTORS

This is a case study in how people think and act with regard to a course of action to achieve an objective. To appreciate the ethical issues posed by this project, some background discussion of how people respond when undertaking to achieve an objective will be helpful. It is also helpful to appreciate that a group of people may *overtly* express a common objective, but individuals or sub-groups may have *covert* objectives. For example, the overt objective of the Paris congress was to arrive at an international consensus on a route and configuration for a maritime canal linking the

Atlantic and Pacific Oceans. It is suggested here, however, that the French organizers of Paris congress may have had a covert objective to assure that any such canal would be designed, constructed and controlled by French interests. To consider the ethical issues raised by the French enterprise to lead and control the development of a trans-oceanic maritime canal it is useful to refer the psychological concepts of “linear” and “non-linear” thinkers.

4.1 Linear and Non-Linear Thinkers. The way people think and act has been said by psychologists and others to fall into two fundamental categories: *Linear Thinkers* and *Non-Linear Thinkers*. Some people may have characteristics of both categories, but one or the other behavior pattern tends to dominate. Here is how these categories have been described.

4.1.1 Linear Thinkers. Linear thinkers are driven by rules. When presented with an issue, they apply recognized and accepted rules and reason logically to a conclusion that is driven by those rules. Engineers are classic examples of linear thinkers. Engineers are trained in engineering schools in the irrefutable laws (or “rules”) of applied physics and they learn a methodology to apply those laws to engineering problems in order to arrive at a correct solution. These are the “theoretical” rules. In engineering practice engineers also learn and apply “experiential” rules. These are rules based on the engineering community’s totality of experience over hundreds of years and millions of design and construction projects throughout the world. This experiential knowledge is incorporated into codes, regulations and accepted best practices. Engineers are not the only examples of linear thinkers. Medical doctors, scientists and accountants are some other linear thinkers. Figure 3 is a picture of how a linear-thinker gets from a problem (Point A) to a solution (Point B).

A linear thinker arrives at Point B by logical application of rules, not because Point B is a pre-determined goal. But this is not how non-linear thinkers get from Point A to, perhaps…. Point B….or Point C or Point D, depending on which is his or her goal.

4.1.2 Non-Linear Thinkers. Non-linear thinkers are not concerned about rules. They are concerned about getting from "Point A to Point C." Point A is the situation with which they are currently confronted and Point C is where they want to be. They are "goal-oriented." For example, if a non-linear thinker is currently a clerk in the mail room of a large corporation (Point A) his goal may be to become Chief Executive Officer of that large corporation (Point C). His goal is not to design a big dam (Point B). He wants to be Chief Executive Officer of that large corporation (Point C). Figure 4 is a picture of how a non-linear thinker gets from where he is now (Point A) to where he wants to be (Point C).

4.2 What Motivates Public Policy Makers? Public policy makers….elected public officials, public officials appointed by elected public officials, and higher level civil servants whose careers are driven by appointed and elected officials….are classic non-linear thinkers. Other examples are merchants, marketing executives, and performing artists.

Public policy makers are goal oriented. Their goal is usually either to (a) get re-elected/re-appointed to the office or position they now hold or, more likely, (b) to get elected/appointed to a higher office….a "higher" office being one of greater power, authority and prestige. Their "Point A" is their current position and their "Point C" is the position to which they aspire. And they will do whatever is necessary to move from A to C, in the absence of a personal "moral stricture".[1]

1. Committed public policy makers are rarely constrained by personal moral strictures when undertaking to achieve a goal such as election to a higher political office. The only stricture that commonly applies is that they will not do anything that will result in a risk of going to jail. But admittedly some small number of public policy makers are sufficiently committed to a particular philosophical position (say, environmental or religious principles) that they will not violate them in order to achieve an objective such as getting elected to a higher political office.

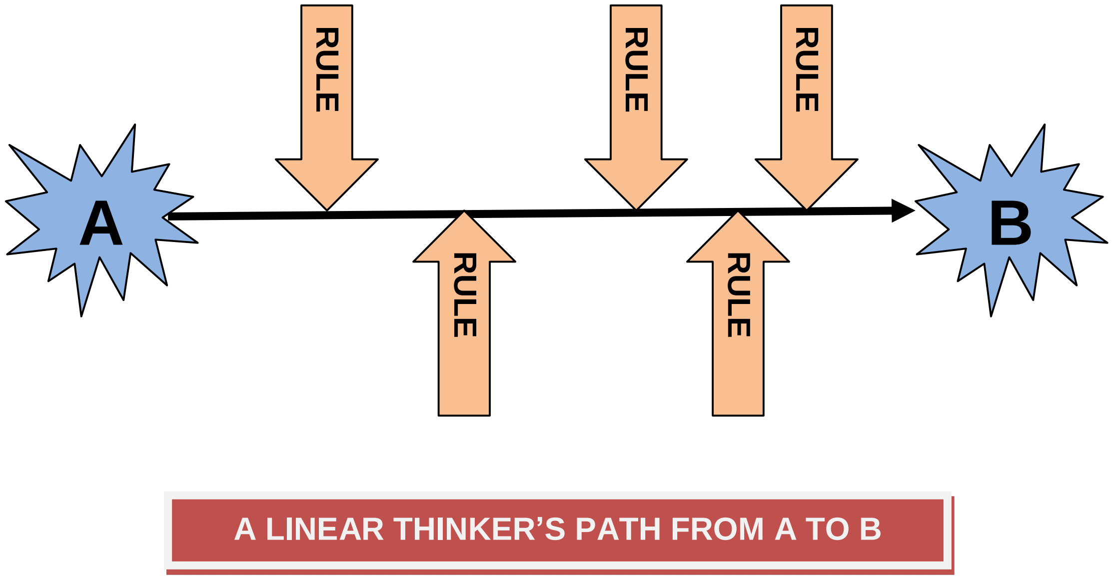

Figure 3

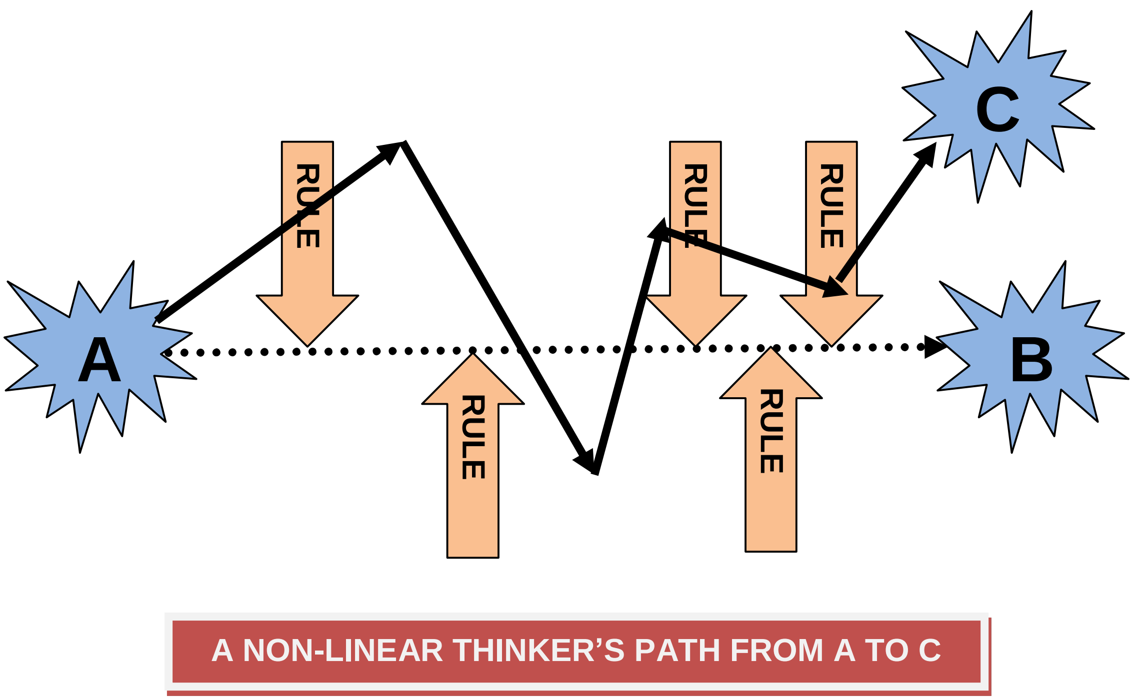

Figure 4

4.3 The Key Policy-Maker for the French Attempt to Build a Panama Canal. The dominant policy-maker in the French attempt to build a trans-oceanic canal across the isthmus of Panama between the Atlantic and Pacific Oceans was Ferdinand DeLesseps. DeLesseps was born in 1805. He studied law, was appointed by the French government as an assistant to his uncle who was the ambassador to Portugal, and he later served the French government as an assistant to his father who held diplomatic positions in Tunisia and Egypt.

Relationships he developed with the ruling family of Egypt resulted in his leadership of an undertaking by French governmental and commercial interests to build a canal between the Red and Mediterranean Seas….the Suez Canal. The Suez Canal was successfully constructed under his leadership.

Because of his successful leadership of the French undertaking to build the Suez Canal, French governmental and commercial interests appointed him to lead the French undertaking to build and control construction of a Panama Canal. At the time of the Panama Canal undertaking DeLesseps was in his advanced years.

DeLesseps was not a professional engineer. An examination of his life indicates he was a "politician"….not in the sense of being an elected public official…. but clearly one who was experienced and effective in dealing with governmental, commercial and financial policy makers at the highest levels of French society. He was successful in his leadership of the French undertaking to build the Suez Canal and this is certainly to his credit, but the Suez Canal was not the monumental engineering challenge that was the Panama Canal. The Suez Canal did not require engineering evaluation of alternative fundamental routes, it was a sea level canal without the need for locks or other sophisticated hydraulic control structures, and it did not present significant soil mechanics issues.

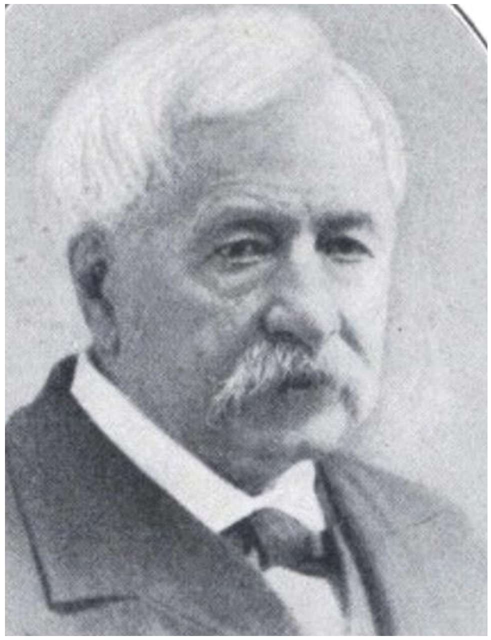

Figure 5
Ferdinand DeLesseps

5. THE ETHICAL ISSUE

The fundamental ethical issue illustrated by the failure of the French effort to develop a Panama Canal is

Major engineering projects should not be controlled by non-engineers.

There are two reasons major engineering projects should not be controlled by non-engineers:

5.1 Training in Underlying Physics is Essential. Engineering is the art and science of applied physics. Whatever the engineering project, whether it is civil, mechanical or electrical in nature, it involves application of principles of physics. This means it is essential that persons who control major engineering projects be able to recognize what principles of physics must be applied and how they are employed. This cannot be done by persons who have not been trained in the underlying physical principles that apply to the project. The fact a person may have learned something about a narrow segment of engineering technology is in no way qualification to manage and control a major engineering project. Comprehensive training in the underlying principles of physics is essential because only with that knowledge can a manager understand what engineering methods must be employed and how they must be applied. For example, only with training in the theory of soil mechanics can a manager make decisions about the nature and extent of soil investigations that must be undertaken before decisions about foundation systems can be made for a building design. Or, only with training in the theory of structural analysis can a manager make decisions about the selection and utilization of structural materials for a building.

5.2 Linear Thinking is Essential. Management of major engineering projects must be controlled by the rules of applied physics, that is, the rules of engineering. This means leadership of a major engineering project must be in the hands of a person who is "rule-driven", that is, a linear thinker. Non-linear thinkers cannot properly manage a major engineering project because their goal-oriented personalities will sooner-or-later drive them to ignore rules of engineering in pursuit of the goal of completing the project on-time and within budget and this, as history has shown, can lead to costly and sometimes tragic consequences.

5.3 The French Panama Canal Project. The French Panama Canal project was controlled by Ferdinand DeLesseps who was not a professional engineer. He was a politician. DeLesseps was a leader in organizing the Paris Congress, was chair of the all important Technical Committee that determined the route and configuration of the canal, and was president of the French company formed to develop a Panama canal. DeLesseps performed admirably in his earlier leadership of the Suez Canal company but his lack of engineering training and experience together with his clearly non-linear thinking, goal orientation caused him to make decisions and take actions that resulted in a costly and tragic failure in Panama.

There are five areas where his leadership was inadequate and led to the project's failure. These are the engineering issues that were presented to DeLesseps by this project and not appropriately addressed. The failure to properly address these issues illustrates how political and commercial interests were able to control a monumental engineering project with disregard of engineering issues.

5.3.1 Inadequate Investigation of Existing Conditions in General. The purportedly international congress convened by French governmental and commercial interests had overwhelming voting control of both its Technical Committee and the Congress itself. French interests were vested in the Panama route because the French had an exclusive right (the Wyse Concession) to develop a canal across the Panama isthmus. Within two weeks of convening the Paris Congress the Technical Committee and voting delegates, with minority professional engineering participation, approved a trans-oceanic canal between the Atlantic and Pacific oceans consisting of a specific route and configuration with minimal engineering information about existing conditions at the proposed Panama Canal route or its alternatives at Nicaragua and Tehuantepec.

5.3.2 Inadequate Investigation of Alternative Routes and Configurations. Control of decisions on the route and basic configuration of the transoceanic canal was vested in the French controlled congress and its Technical Committee. The Committee and Congress did not in any meaningful sense investigate alternative routes and had no substantive information about topographic, geologic, and hydrologic conditions on the Panama route upon which to base engineering decisions about the canal's configuration. The reality is that the French delegates who held voting control on the Technical Committee and Congress were pre-disposed in favor of the Panama route upon which French interests held an exclusive concession from the government of Columbia….the Wyse Concession. In the absence of essential engineering information and without substantive consideration of alternative routes and configurations, the Technical Committee and Congress approved a canal that could only be developed utilizing the Wyse concession route.

5.3.3 Inadequate Investigation of Geological Conditions. The French-sponsored international congress provided the Technical Committee and delegates with minimal information and professional engineering analysis regarding geological conditions along the route proposed across Panama. Construction was precipitously begun but soil and climatic conditions posed enormously challenges. For example, highly saturated soil conditions at many locations along the canal route caused major failures (slides) shortly after completion of cuts and excavations that required extensive re-excavation and configuration changes.

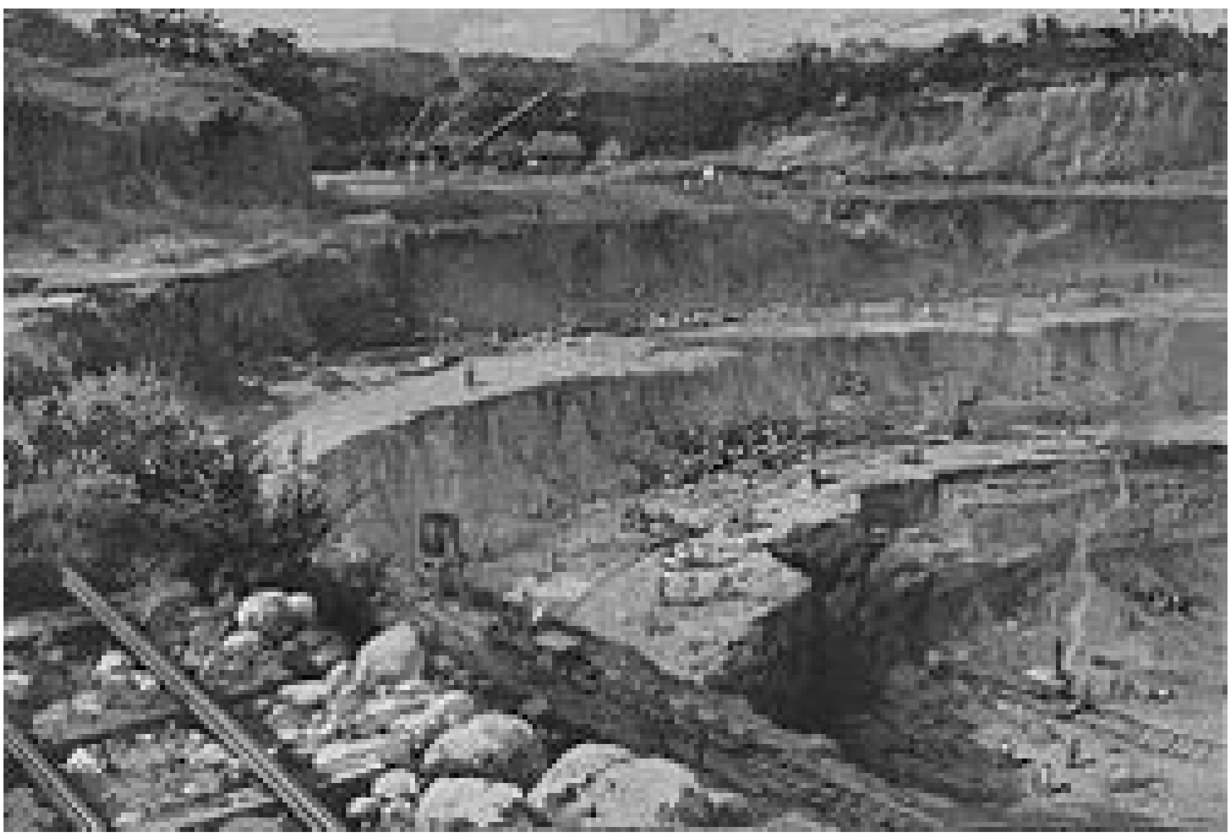

Figure 6
Excavation Work at Culebra Hill; note side slopes

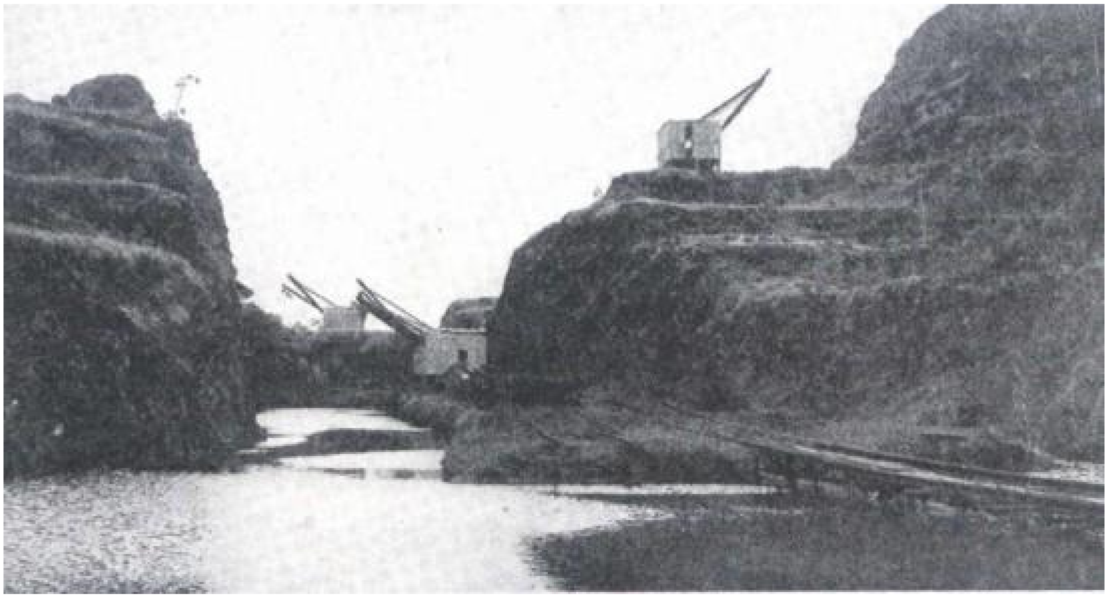

Figure 7
French dredging operations; note side slopes

The French pressed forward with major excavation work without first investigating, testing and evaluating soil conditions. They proceeded with excavation based on steep slopes that were impractical given the highly saturated soil conditions. The result was many costly slides that required re-excavation. It is reasonable to speculate that if a trained professional engineer was in control of the project a comprehensive program of subsurface investigations (soil borings) would have been undertaken, laboratory tests conducted, and appropriate analytical methods used to estimate appropriate angles of repose for excavation slopes.

5.3.4 Inadequate Investigation for Chagres River Control. A fundamental challenge to construction of an Atlantic-to-Pacific canal in Panama was the Chagres River. No matter what configuration might be adopted for a Panama Canal, it would have to be transected by the Chagres River. The Chagres River routinely and seasonally experienced very large flow fluctuations. This would make operation of a canal extremely difficult if not impossible. To resolve this challenge would require extensive evaluation of major hydraulic control structures, such as dams and locks, in order to develop a practicable project. Delegates to the Paris Congress had no credible engineering information and analysis upon which to base their route and configuration decisions. DeLesseps was a leader in organizing the Congress that adopted the Panama route and configuration, was chair of the Technical Committee which recommended the Panama route and configuration to the Congress's voting delegates, and was subsequently president of the French company that undertook the design and construction of a Panama canal. Most of these design and construction decisions and actions were made and undertaken without first developing an engineering plan for control of the Chagres River.

5.3.5 Inadequate Investigation for Tidal Control. At the time of the Paris Congress it was known that there were major differences in tidal fluctuations between the Atlantic and Pacific sides of the Panama isthmus. It was recognized by competent professional engineers that these would present a serious operational problem that would require major hydraulic control structures….such as locks. The Congress, Technical Committee and canal company led by DeLesseps all ignored this major engineer issue and adopted a sea level configuration (i.e. without locks) for the canal that could not possibly accommodate these tidal fluctuations. At the time the French construction effort collapsed, a plan still had not been developed for tidal control.

6. LESSONS LEARNED

Hindsight is a wonderful thing. It is easier to look back and criticize than to look forward and identify and address engineering issues on major projects. In fairness, it is also important to acknowledge that at the time of the French Panama canal undertaking the engineering theory applicable to this project was not as developed as it is today and the civil engineer's experiential knowledge base was less than what is now available. That having been said, there were serious failures to exercise appropriate engineering judgment on the part of Ferdinand DeLesseps and others in the project's leadership cadre that resulted in a failed project and catastrophic financial losses. Considering that a large quantity of the excavation and construction work undertaken by the French company was of no value when the project was ultimately purchased, taken over, and completed by the United States government, the substantial loss of life attendant to that

French construction effort was unnecessary and most unfortunate. Out of this comes one overriding ethical lesson to be learned by engineering professionals *and* the public and private policy makers with whom engineers routinely engage when major engineering projects are undertaken. This is:

6.1 Major engineering projects and programs must be controlled by competent professional engineers. There will be times with all engineering projects and programs when the state of technical knowledge (both theoretical and experiential) can conflict with project goals (i.e. get the project done on-time and on-budget). This conflict needs to be controlled and managed by engineering professionals with appropriate training and experience. Engineering professionals responsible for a project must have full and final authority on all engineering decisions including budget decisions. This is not a self-serving point of view of professional engineers. It has been validated time and again through the years by a substantial number of project failures, including this failed French attempt to build a Panama canal. There are two very convincing reasons why this is so. They are:

6.1.1 Persons in control of major engineering projects and programs must have professional training and experience; technical experience is insufficient. Professional engineering training is essential because it teaches future engineers the principles of applied physics which are the foundation of engineering practice. Without training in the principles of applied physics no person can possibly determine which principles of physics apply to a specific project and what investigations and analytical methods must be employed in order make the many engineering decisions regarding materials and methods in order to successfully design and construct a major engineering project. Professional engineering experience is essential because only through experience designing and constructing comparable projects can a person be aware of and understand how to apply the experiential engineering knowledge base to the project being undertaken. A limited amount of knowledge about a narrow spectrum of engineering methods and materials is in no way sufficient for a person to manage and control a major engineering project. Persons with such limited knowledge can generally be characterized as engineering technicians. Engineering technicians are a valuable and important part of the engineering team but they do not have the necessary training in the theory of applied physics that is the foundation of the art and science of engineering practice. History is replete with projects that were entrusted to the control of engineering technicians that had unfortunate if not disastrous results.

6.1.2 Persons in control of substantive engineering projects and programs must be linear thinker. A major engineering project must be controlled by a linear thinker. A major engineering project must be planned, designed and constructed in accordance with the rules of engineering (applied physics). It follows that the person or persons in control of a major engineering project must be rule-driven, that is, linear thinkers. They must have the personal characteristics that move them to apply rules to a project and that the result of application of those rules is the proper project configuration and construction. Non-linear thinkers should never be put in charge of a major engineering project because their goal-orientation ("I want the project to look like this, and be completed on-time and on-budget") will often lead them to make decisions that are contrary to the rules of engineering. History has demonstrated that this can lead to disastrous results on projects. The French undertaking to build a Panama canal was controlled by a career politician. He was an effective leader in many ways but not competent to control a major engineering project because a retrospective examination of his life clearly indicates he was a non-linear thinker.

6.2 Professional engineers should have training in implementing major engineering projects and programs in an organizational setting in which non-linear thinkers may be influential or even dominant. Engineering professionals need training in how to work in organizations (companies and agencies) where goal-oriented non-linear thinkers are influential or even dominant. They need the inter-personal skills that are essential to implementing substantive engineering projects and programs that fall prudently within the scope of available theoretical and experiential knowledge. These skills can help to prevent the ascension of unqualified persons to positions of control over engineering decisions.

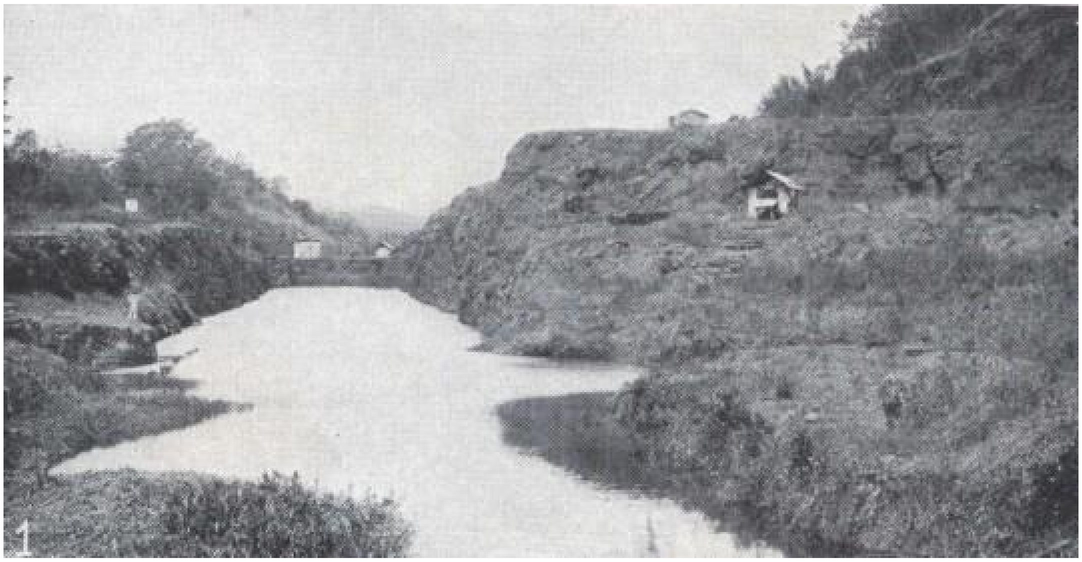

Figure 8
The abandoned French canal; note side slopes

QUIZ

Ethical Issues from the Panama Canal Failure

1. Which of the following was a country that was not the site of a route under consideration for an Atlantic-to-Pacific maritime canal in the 1880s?

   a. Columbia
   b. Nicaragua
   c. Mexico
   d. Honduras

2. ____________ was one of the four facets of the failed attempt to build a Panama canal.

   a. Maritime provinces
   b. Jurisprudence
   c. Health safety
   d. Air rights

3. An Atlantic-to-Pacific maritime canal across the isthmus of Central America provides a New York-to-California maritime route that is about ______ percent of the distance of one around Cape Horn at the southern tip of South America..

   a. 25
   b. 45
   c. 65
   d. 85

4. Alexander __________ was one of the first to suggest the possibility of constructing a maritime canal from the Atlantic to Pacific Ocean across Central America.

   a. Bell
   b. von Humbolt
   c. Peary
   d. von Allmen

5. The exclusive concession to construct and operate an Atlantic-to-Pacific maritime canal across the isthmus of Panama was granted French interests by the government of _________.

   a. Nicaragua
   b. Panama

c. Columbia
d. Mexico

6. A major engineering challenge faced in constructing an Atlantic-to-Pacific maritime canal across Central America was ____________.

a. wind loads
b. tundra plains
c. differential tidal fluctuations
d. desalination

7. The international congress convened in 1879 to develop a consensus plan for a maritime canal across Central America was controlled by __________ interests.

a. United States
b. French
c. Columbia
d. Panamanian

8. A major engineering challenge faced in construction an Atlantic-to-Pacific maritime canal across the isthmus of Panama was control of the ______________ River.

a. Miraflores
b. Chagres
c. Colon
d. Pedro Miguel

9. The subsequent successful construction of the Panama Canal by the United States included construction of a dam at ____________.

a. Gatun
b. Colon
c. Culebra
d. Pedro Miguel

10. A natural feature that mitigated in favor of a Central American canal across Nicaragua was Lake ____________.

a. Gatun
b. Nicaragua
c. Alajuela
d. Plantine

11. Linear thinkers are ____________ driven.

a. goal

b. aesthetics
c. environmentally
d. rule

12. Non-linear thinkers are _____________ driven.

a. goal
b. aesthetics
c. environmentally
d. rule

13. The key policy-maker in the French attempt to build a Panama Canal was ________.

a. Lucien Wyse
b. Napoleon Bonaparte
c. Ferdinand DeLesseps
d. William Gorgas

14. Tidal fluctuations on the Pacific side of the isthmus of Panama are in the range of 10 to _____ feet.

a. 20
b. 30
c. 40
d. 50

15. Tidal fluctuations on the Atlantic side of the isthmus of Panama are __________

a. greater than anywhere else in the world
b. more than those on the Pacific side
c. less than those on the Pacific side
d. non-existent