



INTEGRATED TURF NUTRITION (ITN) ANALYSIS

Prepared for:
Greywolf Golf Course
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Better Technology. Better Agronomy. Better Turf.

Key Points

- **Soil pH of the greens has dropped below the critical 8.5 level, back to historic norms.**
- **Soluble salt (EC) and sulfate levels are still elevated in fairway 10.**
- **Organic matter levels appear to be increasing in the greens, likely due to thatch and mat accumulation.**
- **P levels have increased dramatically in the greens, reversing a downward trend.**
- **K & Mg remain deficient in the greens and tees, a common problem in low CEC calcareous sand soils.**
- **Mn is deficient in the greens. Zn is deficient in the greens and tees.**
- **Nutrient additions from irrigation water (S and Mg) have been fully integrated with your fertility program.**

Soil pH

Soil pH measures the active hydrogen ion concentration, the level of which determines whether the soil is acidic or alkaline. The Buffer Index is measured when soil pH is less than 6.5, which determines the exchangeable hydrogen held in the soil and the amount of lime required to neutralize it.

Managing soil pH maximizes the effectiveness of soil nutrients, which are collectively at their optimum availability between a pH of 6.0 and 7.5. As pH drops below 6.0 phosphorous availability decreases because of aluminum and iron fixation. Below a pH of 5.0 aluminum and manganese become toxic to plants. As soil pH rises above 7.5, phosphorous, zinc, copper, iron and manganese become increasingly insoluble and unavailable. Under high pH conditions soil phosphorous gets "fixed" with soil calcium to become insoluble; a condition that is maximized at a pH of 8.0 (see figure 1).

- 2005 soil tests indicate that your greens have an average pH of 8.2. This compares to an average of 8.1 in 2004 and an average of 8.6 in 2003. After two years the pH of your greens seems to have stabilized below the critical level of 8.5, probably due to increased rainfall and less reliance of irrigation water. Your fairway pH is 7.6 (compared to 7.7 in 2004) and your tee pH is 8.1 (compared to 7.9 in 2004).
- Though obviously higher than the ideal range of 6.5-7.0, these pH levels are natural for your environment which is dominated by calcareous soils and high calcium / bicarbonate irrigation water. Moreover, the pH trend seems to be one of stability.
- Expect pH induced phosphorous and micronutrient deficiencies.

Excess Carbonates

Excess Carbonates measures the amount of free limestone in the soil. Soils high in excess carbonates usually have a high pH. As excess carbonate levels increase so too does the fixation of P, Mn, Zn and Fe. Excess carbonates can be neutralized with acidic materials, however the quantity required to do so can be so large that it may be impractical.

In the right circumstances irrigation water high in bicarbonates and carbonates can cause serious agronomic problems. Upon drying, water borne bicarbonates react with soluble soil calcium to form insoluble calcium carbonate, a reaction that essentially leaves "room" in the soil for other cations to ac-

accumulate. When the irrigation water is also high in sodium a base saturation imbalance can develop as sodium accumulates in the soil. The result is a dramatic increase in soil pH, impaired drainage and a general decline in turf vigor. This can be a particular problem in non-calcareous soils that have a limited ability to supply soluble calcium. However, the condition is much less common in calcareous soils because calcareous environments usually produce high levels of soluble calcium in the soil, offsetting the negative impact of water borne bicarbonates.

Excess carbonates are managed by increasing “free” calcium levels in the soil. This is done through applications of gypsum (calcium sulfate), which replaces carbonate with soluble calcium. Elemental sulfur increases free calcium in calcareous soils by reacting with soil limestone to form calcium sulfate (gypsum). Acid injection of irrigation water destroys bicarbonates before they react with soil calcium and can be very effective tool in specific circumstances (see figure 2).

- Excess carbonates are medium in the greens, and low in both the fairways and tees. Continue monitoring irrigation water quality to determine the impact bicarbonates may be having on soil chemistry.

Soluble Salts

Soluble Salts measures the electrical conductivity of the soil solution, or the salts that are soluble in water. As the Soluble Salt level increases, the plant must exert increasingly greater effort to extract water from the soil. The critical level of Soluble Salts is 0.6 mmhos / cm, at which soil water extraction by the turfgrass plant begins to be impaired. Above a level of 1.0 mmhos / cm, turfgrass roots begin to die-back and vigor can decline. If salt concentrations continue to increase, drought conditions will occur regardless of soil moisture levels.

The “big three” salts are calcium, magnesium and sodium in combination with chloride, sulfate and bicarbonate. The most important salts contain sodium, because of it’s potential to destroy soil structure and reduce water infiltration. Soluble salts leach readily through the soil, so excess levels usually indicate a problem with drainage or a localized high water table.

- Soluble salt levels in the greens and tee samples are low. Fairway 10 continues to have a somewhat elevated EC level of 0.49, though substantially lower than the 2004 level of 0.64. As testing established, the principle factor driving these elevated soluble salt levels is a naturally high level of sulfur in your irrigation water.

Organic Matter (OM)

Organic matter results from the decay process of organic residues, producing stable humus compounds that have active cation holding properties. It also has a very high capacity for holding soil moisture. Organic matter acts as a storehouse for plant food nutrients and improves soil physical structure. Natural soils tend to have higher organic matter than constructed sand based greens.

Recent research indicates that reduced infiltration resulting from organic matter accumulation in the top 1-3” of the soil in greens is directly correlated with summer bentgrass / poa decline. The critical level of organic matter appears to be 3%, above which summer decline can quickly become a problem under the right environmental conditions.

- Greens and tees organic matter levels range from 0.6-1.0%, which is in the ideal range for constructed sand soils. However, we're seeing a slight increase in the organic matter levels of your greens which could be due to thatch accumulation. The natural soils of your fairways have a higher OM range of 3.9-5.9%.

Cation Exchange Capacity (CEC)

CEC establishes the rate at which nutrients (cations) will be stored and released. It is an estimated value, based on the total amount of extracted cations from the soil analysis (Ca, K, Mg, Na, H). A soil with a high CEC has the capacity to hold more cations than a soil with a low CEC. In order to avoid leaching losses, low CEC soils such as sand-based greens require lighter and more frequent nutrient applications than do high CEC soils.

In addition to clay and organic matter pH also has an effect on CEC. As pH increases, soil exchange sites become more active and increasing a soil's pH from 6.0 to 8.5 can result in a 50% increase in estimated CEC. Free limestone (excess carbonates), gypsum and excess soluble salts can also result in an overestimated CEC, particularly on low CEC soils.

- As in previous years high pH, low organic matter levels and low Cation availability, indicate that the CEC of your greens is likely overstated. Fairway and tee samples appear to be closer to normal.
- For your greens and tees, spoon feed N, K and Mg, with frequent and light fertilizer applications. Foliar fertilizers should be used to supplement your soil-based nutrition program.

Nitrate (NO₃)

Nitrate is plant available, accounting for over 90% of the N consumed by turfgrass. Like soil particles nitrate has a negative electrical charge which makes it prone to high rates of leaching. Elevated nitrate levels result from poor drainage or recent fertilizer applications. Testing for nitrate can be a valuable tool in assessing the efficiency and timing of your nitrogen management program.

- Greens, Tees and Fairway soil nitrate levels are exceptionally low.

Phosphorous

Soil phosphorous exists in three different forms: solution P, organic P and inorganic or mineral P. Solution P is immediately available for plant uptake, but is in a constant state of flux between the organic and inorganic P reserves. P also reacts with micronutrients and calcium to form relatively insoluble compounds under low and high pH conditions. This very complex cycle makes it difficult to predict P availability. As a result, numerous extraction methods have been developed to assess P fertility (see figures 3 & 4).

Two P extraction procedures are used by Harris Labs. When soil pH is 7.2 or lower, the Bray test procedure is used and when soil pH is above 7.2, the Olsen test procedure is used. Both report P levels in parts per million but have very different fertility interpretations. For the Bray test 40 ppm is considered adequate, and for the Olsen test 24 ppm is considered adequate.

- Though your greens are still deficient in available phosphorous, we've seen a dramatic increase in P availability this year. The average P level is now 19 ppm, up from 10 in 2004, 13 in 2003 and 16 in 2002. More importantly, this is the first year since we began testing at Greywolf in 2002 where P availability has actually increased rather than decreased. This trend reversal is almost certainly due to a more aggressive approach to P fertility in 2005.
- As I indicated, we're making very positive progress on the P fertility of your greens, but one can still expect spring and fall P deficiencies (characterized by poor turfgrass vigor, drought-like coloration and purple leaf tissue). In order to supply the plant with sufficient P to maintain optimum health and quality, moderate levels of fertilizer P are required. In addition, I suggest that plant P levels be monitored through monthly tissue analysis. Apply foliar P fertilizer in response to systemically low P tissue levels.
- Fairway P levels have also increased and are now at what Harris Labs considers to be a minimum adequate level. Considering your soil pH, calcareous environment and irrigation water quality, I suggest we continue with a maintenance level of P fertilizer for your fairways rather than eliminate P from the program. Maintaining optimum P levels in your fairways will ensure superior spring and fall vigor, while also aiding in divot and winter damage recovery.
- The Tee samples also indicate P sufficiency, again a significant improvement over 2004's results. Much like your fairway program, I suggest continuing with a maintenance level of P fertilizer to optimize turf vigor and divot recovery.

Cations & Base Saturation

Potassium, magnesium, calcium, hydrogen and sodium are the principle soil cations, each having positive electrical charges of varying strength. Soil colloids are negatively charged and act like a magnet in attracting these positively charged cations. The more strongly charged cations displace those with a weaker charge in their competition for space on soil particles. This is the primary reason why gypsum (calcium sulfate) reclaims sodium rich soils, as the relatively weak sodium (Na⁺) is displaced by stronger calcium (Ca⁺⁺). It's also why potassium (K⁺) is often deficient in high calcium soils. Because of this antagonistic relationship, optimizing the balance between the cations is critical to maximizing their solubility and availability as plant food nutrients. This concept is known as Base Saturation and is expressed in percentage terms. In general, as the percentage of soil exchange sites occupied by a given cation increases so too does its availability to the turfgrass plant (see chart 1).

Like other nutrients, the cations should be extracted at sufficient levels (ppm) for optimum fertility. However, constructed sand soils have virtually no clay and extremely low levels of organic matter, resulting in few exchange sites and a poor ability to retain nutrients. The result is heavy leaching of K and Mg. On these soils, base saturation is valuable in assessing cation fertility. Assessing extracted cation levels can be of greater value in gauging the fertility of higher CEC soils, such as fairways.

Calcium

Calcium is rarely deficient in turfgrass and is normally required only as a soil amendment, such as limestone or gypsum. Optimum calcium fertility ranges between 600 and 4500 ppm, depending on soil CEC. Optimum calcium base saturation is 65-75%.

- Extracted Ca levels and Ca base saturation are quite high in all the tests, though relatively lower in the higher CEC fairways. In your high pH calcareous environment, excess Ca in the soil is to be expected. Moreover, high calcium availability will impair K and Mg fertility.
- Its unlikely that your turf will ever experience a Ca deficiency. Ca fertilizer and amendment applications - soil or foliar - are not necessary. Instead, focus on K and Mg nutrition, particularly for your greens and tees.

Potassium

Potassium extracted by the ammonium acetate method is readily available for plant uptake. Optimum potassium fertility ranges between 90 and 300 ppm, depending on soil CEC. Optimum potassium base saturation is 2-7%.

- Available K is extremely low in your greens and tees, which is mirrored by low K base saturation. This is a very common result on calcareous sand-based soils with a low CEC. Given the high leaching potential, K fertility of your greens and tees is best managed by spoon-feeding and with controlled release K fertilizers. Monitor plant K status of your greens through monthly tissue analysis and apply foliar K in response to systemically low tissue K levels.
- Fairways 4 and 5 are low in K, whereas fairway 10 is close to sufficient. A moderately high level of K fertilizer is required.

Magnesium

Magnesium is often deficient in low CEC sand soils. Optimum magnesium fertility ranges between 100 and 500 ppm, depending on soil CEC. Optimum magnesium base saturation is 15-20%.

- Mg is deficient in your greens and tees, reflected by very low Mg base saturation. Mg fertility is best managed by spoon-feeding with highly soluble sulfate forms of magnesium fertilizer, such as K-Mag or Epsom Salts. Monitor plant Mg status of your greens through tissue analysis and apply foliar Mg in response to systemically low tissue Mg levels.
- Mg levels are substantially higher in your fairways and supplemental Mg fertilizer is not required.
- The irrigation water analysis we conducted in the summer of 2005 indicates that 126 pounds of Mg per acre (3 pounds of Mg per 1000 square feet) will be applied to the soil with every acre-foot of irrigation water. Harris recommends Mg fertilizer at 0.6 pounds of Mg per 1000 square feet, a rate equivalent to 1/5 the level applied per acre-foot of irrigation water. Mg fertilizer applications will simply be dwarfed by the amount of Mg applied through irrigation. In my opinion, the best approach to Mg fertility in your circumstance is to conduct monthly tissue analysis on your greens and address Mg deficiencies that arise through foliar Mg applications.

Sodium

Sodium is not a plant food element but it does play a critical role in soil and plant health. When sodium base saturation exceeds 5% soil clay particles disperse or “run together”, reducing water infiltra-

tion rates and impairing plant growth. Sand soils can tolerate higher sodium base saturation levels due to their relatively low clay and organic matter content and the fact that their drainage properties are primarily based on a coarse textured soil. Gypsum can be used to reclaim sodium rich soils by replacing the sodium with calcium. Soils with a pH over 8.5 often have a sodium problem.

- Extracted Na levels are very low in all tests. More importantly, Na base saturation does not exceed 0.5% in any soil tests.

Sulfur

The sulfate form of sulfur measured in soil testing is soluble in the soil solution and prone to leaching. Elevated levels of sulfate are usually the result of poor soil drainage or a recent fertilizer application.

- Sulfate levels are high in the fairways, moderate in the tees and low in the greens. Poorly drained fairway 10 has 73 ppm of sulfate, which is contributing to the elevated levels of soluble salts in the soil.
- The 2005 irrigation water analysis revealed that approximately 60 pounds of S per acre will be applied with every acre-foot of irrigation water. Turf requires 30-40 pounds of S per acre as a maintenance fertility level. When the sulfur from your irrigation water is combined with sulfur from your fertility program, its easy to see how sulfate and soluble salt levels can increase in the soil.
- Continue to monitor sulfate levels and soluble salts through annual irrigation water analysis and annual soil analysis.

Zinc

Zn becomes plant available through the decay process of organic matter, so constructed sand soils with low organic matter are often deficient. Over time Zn levels can be built to sufficient levels with fertilizer applications. High soil pH will restrict zinc availability. Optimum zinc fertility is 2-4 ppm.

- Like 2004, Zn levels are deficient in your greens and tees but sufficient in the fairways. Build levels of supplemental Zn fertilizers are required for optimum nutrition on your greens and tees. Monitor greens Zn status through tissue analysis and apply foliar Zn only in response to systemically low tissue Zn levels.

Manganese

Like Zn, Mn becomes plant available through decaying organic matter and is often deficient in constructed sand soils. Manganese availability is highly reactive with soil pH. Optimum manganese fertility is 4-12 ppm.

- Like 2004, Mn levels are deficient in the greens but adequate in the fairways and tees. Build levels of supplemental Mn fertilizers are required for optimum nutrition on your greens. Monitor green plant Mn status through tissue analysis and apply foliar Mn only in response to low Mn levels.

Copper

Cu deficiencies tend to be more rare than that of Zn and Mn. High soil pH restricts copper availability. Optimum copper fertility is 0.5-2 ppm.

- Cu levels are sufficient in all tests.

Iron

Fe fixation can be very high on soils with a pH in excess of 8.0, requiring multiple fertilizer applications every year. Optimum iron fertility is 7-20 ppm.

- In spite of you high soil pH, Fe levels are all adequate. As a result, soil applied chelated or complexed Fe fertilizer, in addition to foliar Fe fertilizer, offer the best potential for a color response.

Boron

Unlike the other micronutrients, B is relatively soluble in the soil solution and is somewhat prone to leaching. Optimum boron fertility is 0.5-1.5 ppm

- B levels are sufficient.

FUSION ITN Nutrient Requirements (pounds / 1000 unless otherwise noted)

	<u>Fairways</u>	<u>Greens</u>	<u>Tees</u>
N	2 - 2.5	4.5	4.5
P2O5	0.5	2	0.7
K2O	2.4	5	5
Mg			
S			
Zn		4-5 per acre	4-5 per acre
Mn		4-5 per acre	
Fe	3-5 per acre	5-10 per acre	5-10 per acre

- Iron is recommended for color enhancement, not to address a nutrient deficiency.
- Nitrogen recommendations for greens are intended as a base. Nitrogen nutrition should be fine-tuned with soil and foliar applications to suit individual management practices.
- For the greens, tees and fairways sufficient sulfur will be supplied through a combination of fertilizer and irrigation water.
- Sufficient Mg will be applied to the soil from irrigation water.
- Monitoring greens nutrient status through monthly tissue analysis is recommended. Fine tune plant nutrition with foliar fertilizer when prescribed.

FUSION Fairway ITN Program

The following prescription formulations are based on your soil test results and will provide optimum soil-based nutrition for your fairways. All the prices noted are *before* fall booking or early payment discounts.

SPRING application: FUSION fairway-grade 16-4-9.6-17S-0.9Fe with all nitrogen from ammonium sulfate. Two applications at 140 pounds per acre (each delivering 1/2 pound N per 1000 square feet), for a total of 1 pound of N per 1000 square feet.

- 305 bags required for 60 acres
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SUMMER application: FUSION greens-grade 18-4-21-13S-0.3Mn-0.6Fe with 50% nitrogen from PCSCU. Two applications at 125 pounds per acre (each delivering 1/2 pound N per 1000 square feet), for a total of 1 pound of N per 1000 square feet.

- 273 bags required for 60 acres
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LATE SUMMER / EARLY FALL application: FUSION greens-grade 14-0-32-15S-0.4Fe with 50% nitrogen from PCSCU. One application at 90 pounds per acre, for a total of 1/4 pound of N per 1000 square feet.

- 95 bags required for 60 acres
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ROUGH applications: FUSION fairway-grade 25-5-15-3S-1.5Mg-0.5Fe with 60% nitrogen from DURATION. Two applications at 175 pounds per acre (each delivering 1 pound N per 1000 square feet), for a total of 2 pound of N per 1000 square feet.

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FUSION Greens & Tees ITN Program

The following prescription formulations are based on your soil test results and will provide optimum soil-based nutrition for your greens and tees. They contain AMINOUREA as a source of controlled release nitrogen, for season long release with minimal mower pick-up. FUSION fertilizers are formulated with M-KOTE dispersible micronutrients, offering nutrient coverage and response superior to traditional granular products. They also contain CrK controlled release sulfate of potash, which will help reduce K leaching and improve K utilization. All the prices noted are *before* fall booking or early payment discounts.

Greens & Tees Spring Applications: FUSION 14-14-14-7S-4Ca-0.9Fe-0.4Mn-0.1Zn with 60% AMINOUREA nitrogen, 50% CrK Potash and M-KOTE micronutrients. Apply every 2-3 weeks at 3.6 pounds / 1000 for 0.5 pounds of N per application. 2 applications in total.

- 58 bags required for 10 acres
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Greens & Tees Summer Applications: FUSION 18-3-20-10S-0.9Ca-1.1Fe-0.5Mn-0.1Zn with 60% AMINOUREA nitrogen, 50% CrK Potash and M-KOTE micronutrients. Apply every 2-4 weeks at 2.8 pounds / 1000 for 0.5 pounds of N per application. 6 applications in total.

- 138 bags required for 10 acres

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Greens & Tees Fall Applications: FUSION 14-14-14-7S-4Ca-0.9Fe-0.4Mn-0.1Zn with 60% AMI-NOUREA nitrogen, 50% CrK Potash and M-KOTE micronutrients . Apply every at 3.6 pounds / 1000 for 0.5 pounds of N per application. 1 application in total.

- 29 bags required for 10 acres

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Supplemental foliar fertilizer, for bentgrass applications with Primo:

- FERTIFLO 15-5-5-1Fe + micros. 2 litres per acre.
- IRONMAX 4% Fe. 2 litres per acre.

Supplemental liquid and foliar fertilizer, as required by tissue analysis or local management practices:

- SOLEX 6-24-6 (soil or foliar) as required when P is deficient.
- SOLEX 0-0-30 (soil or foliar) as required to boost K reserves.
- SOLEX 3-18-18 (soil or foliar) as required when P and K are both deficient.
- SOLEX 28-0-0 with 72% CRN (soil) as required to boost vigor.
- FERTIFLO 15-5-5 + micros (foliar) every 2-4 weeks to boost vigor.

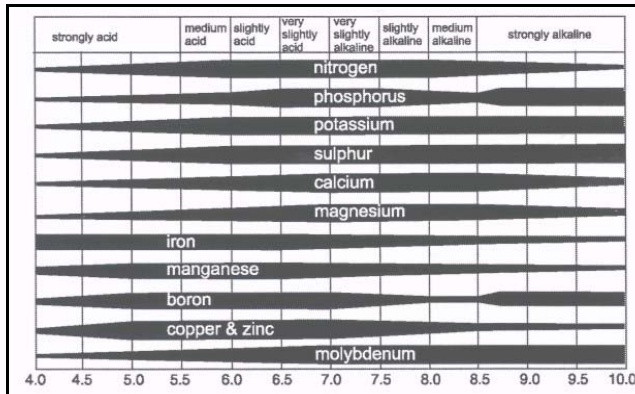


Figure 1: The effect of soil pH on nutrient availability

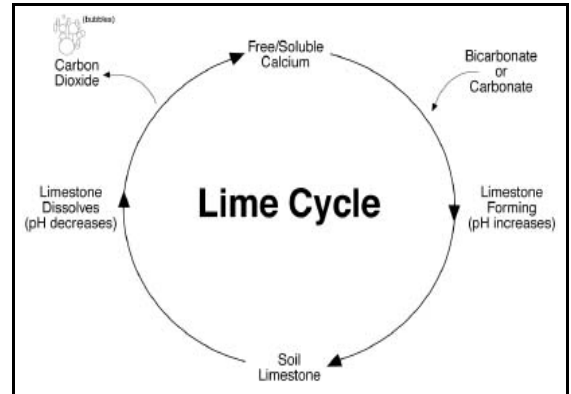


Figure 2: The lime cycle

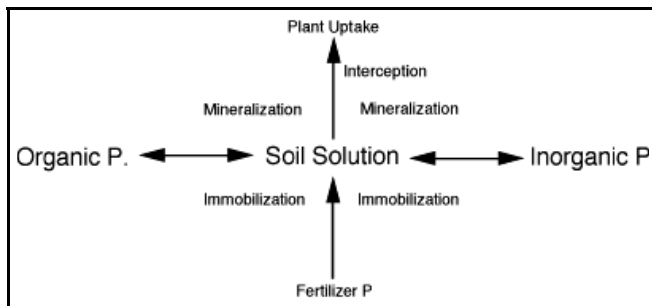


Figure 3: The complex phosphorous - soil relationship

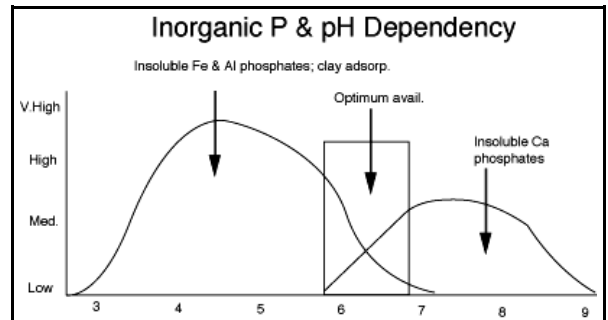


Figure 4: pH and P availability

Optimum % Base Saturation Levels				
<u>Hydrogen</u>	<u>Potassium</u>	<u>Magnesium</u>	<u>Calcium</u>	<u>Sodium</u>
0-5%	2-7%	15-20%	65-75%	0-5%

Chart 1: base saturation